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A SPECIAL ISSUE

H. R. L. STREIGHT, F.C.I.C.

Conference Chairman,

A.I.Ch.E.-C.I.C. Chemical Engineering Conference

THIS special issue of "The Canadian Journal of Chemical Engineering" contains the complete papers which were delivered in English by highly qualified and eminent European executives and professors in the symposium "The Chemical Industry in Europe Today" at the Canada-U.S. Chemical Engineering Conference. Sponsored by the American Institute of Chemical Engineers and The Chemical Institute of Canada, Chemical Engineering Division, the Conference was held in Montreal, April 20-23, 1958. Although the subject matter of most of the papers lies outside the fields covered by this Journal, the Editorial Board approved their publication in a special issue because it was felt they were of general interest to chemical engineers.

For the first time in North America, topical and authoritative accounts of the chemical industry in Great Britain, France, the Benelux countries (Belgium, Netherlands), West Germany, Italy and the U.S.S.R. were heard by nearly 1,400 engineers and scientists. In a world where distance becomes less and less significant, the development of European chemical products and processes is becoming ever more important to us in North America. Canada's role in world affairs has often been described as that of an intermediary and with this in mind the Conference Committee decided to invite well-known European speakers to interpret for us, the progress and development of the European chemical industry. It was hoped that the participation of the Soviet scientists might open a door for the future exchange of scientific knowledge between East and West.

We in North America owe a great debt to European chemistry. Many of our chemical products and processes first saw the light of day in Europe or owe their present existence to European scientific discoveries. For instance, Baekeland was the father of the plastics industry, Chardonnet started the manufacture of "artificial silk" and Perkins revolutionized the dye industry. Recently Whinfield discovered a polyester fibre, and Ziegler a catalytic process for the production of new olefin polymers. The European chemical industry is increasing at a spectacular rate; in 1956 the order was: U.S.A., West Germany and Great Britain. Future expansion depends greatly on the nature of the raw materials as described in the papers. Coal is giving way to oil as a basic raw material and the European petrochemical industry is expected to expand rapidly with the additional production of polyethylene, synthetic rubbers, plastics and synthetic detergents.

We have heard of the rapid advances made in the discovery and production of plastics and synthetic fibres, including polyethylene and polyester fibres found and first produced by Imperial Chemical Industries Limited; the great strides made by the French chemical industry in developing petrochemical products, based on the discovery of oil in the Sahara Desert, and the Hoechst process for producing and adding hydrocarbon fractions in the direct manufacture of intermediates for dyestuffs, plastics and synthetic fibres. Recently at the 26th Exposition of Chemical Industries, great interest was shown in polypropylene displayed by Montecatini. Further research on copolymers of ethylene and other olefins and the new method of Société Carbochimique for producing propylene oxide, opens a new door to chemical products. Less is known of chemical production in the U.S.S.R., although we have heard from visitors of the emphasis placed on scientific training and on the greater number of engineering graduates in the U.S.S.R. than in U.S.A. Before this Conference, we in North America had not heard a Soviet account of their chemical industry or education.

The reconstruction of Europe's chemical research effort has been rapid and effective. For instance, the amount invested in research and development by one European chemical company is more than 5% of annual sales. The increase of its annual sales by 16% was largely based on products not marketed five years ago.

Chemical exports from Europe are increasing year by year, currently they constitute about 25% of British and West German production, 33% of Italian and 50% of Benelux manufacture. The forthcoming common market and free trade area of Continental Europe, the expansion of the European chemical industry and its increased export sales are of great importance to the chemical industry of North America.

The review of the chemical industry in Great Britain was given by Dr. A. Holroyd, Deputy Chairman of Imperial Chemical Industries Limited, London—one of the oldest and most aggressive chemical firms in Europe with subsidiaries in many parts of the British Commonwealth. M. J.-J. Desportes, President Director-General of Etablissements Kuhlmann, Paris, discussed the chemical industry in France and showed the expansion of the industry into the petrochemical field. He was accompanied by Dr. J. Brocart, Director of Research. Prof. Dr. Karl Winnacker, President of Farbwerke Hoechst, A.-G., Frankfurt, reviewed the expansion of this large Western German chemical firm which has sales offices in Canada and the U.S.A. The Director of Research, Dr. O. Horn, was with him during his address. Dr. P. Ferrero, Director of Research for Société Carbochimique and Société Carbonisation Centrale, Tertre (near Brussels) examined the fields

of growth in the Benelux countries and Prof. G. Natta, an outstanding figure in the development of new types of plastic materials, who represented the Polytechnic Institute of Milan and the giant Italian chemical company, Montecatini, which has a subsidiary in New York, discussed the Italian chemical industry and his recent discoveries in the field of polymers. Developments in the chemical industry of the U.S.S.R. were outlined by Prof. N. Melnikov of the Institute of Fertilizers and Insectofungicides, Moscow; advances in Russian chemical engineering education, by Dr. V. Aleskovskij of the Institute of Technology, Leningrad. They were accompanied by S. F. Filipytchev, Moscow.

The free exchange of ideas between nations is deemed essential to technical progress and it is my personal hope that in bringing together engineers and scientists of European and North American countries, we have furthered the cause of international goodwill and paved the way to greater co-operation and understanding between the chemical industries of these countries. May other international chemical engineering conferences be held in Canada.★

The Authors . . . .

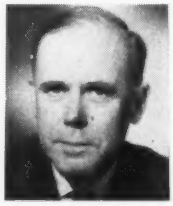
Karl Winnacker was born in Barmen, Germany, and studied chemistry at Technische Hochschule in Braunschweig and at Technische Hochschule in Darmstadt. After graduation at the latter, he remained as a member of staff until 1933 when he joined I.G. Professor Winnacker occupied a number of positions in the research and operating departments of this company. He was appointed president of Farbwerke Hoechst A.-G. in 1952. Dr. Winnacker is an honorary professor at Frankfurt University, chairman of DECHEMA, and vice-chairman of the West German Atomic Commission. He is the author of a number of articles and patents and is co-publisher of the Ullman "Encyclopaedia of Technical Chemistry" and publisher of the Winnacker-Weingaertner "Chemical Technology".

• • •

Ronald Holroyd is a graduate in chemistry from Sheffield University where he spent a further three years on coal-oil research. Dr. Holroyd did additional research on this subject at Imperial Chemical Industries at Billingham, and is now a recognized authority on this subject. At the end of World War II, he investigated fuel developments in Germany. In 1947, he was appointed director of the research division at Billingham, and Division Technical Managing Director in 1950. In 1952, he was appointed research director of I.C.I. and in 1957 became deputy chairman. He is also a director of Canadian Industries Limited.

• • •

Giulio Natta obtained his doctorate degree in chemical engineering from the Polytechnic School of Milan. Between 1933-1939, he was successively professor at the Universities of Pavia, Rome and the Polytechnic of Turin before returning to the Polytechnic of Milan. He has studied extensively the Italian production of synthetic rubber especially butadiene production and its separation from butene-1. Professor Natta has published 245 papers describing research in the fields of structure of solid organic and inorganic compounds by X-ray and by electron diffraction, kinetic researches on the synthesis of of methanol and on successive reactions. His kinetic studies have recently been extended to processes of ethylene polymerization by aluminum alkyls with the production of isotactic, atactic polymers including the industrial development of isotactic polypropylene.



Jean-Jacques Desportes is a graduate in mining from Ecole Polytechnique and following graduation he spent two years at L'Ecole Supérieure des Mines in Paris. After holding a number of official administrative posts he became vice-president and director general of Omnium Francois des Pétroles. In 1945, M. Desportes joined the Etablissements Kuhlmann as joint director-general and is now president director-general of this firm and of la Compagnie Francaise des Matiéres Colorantes. The field of activity of these two companies cover basic chemical products, plastics, rayon, organic products and dyestuffs. He is also a director of chemical companies in France, Belgium, Morocco, Argentine and Brazil.

• • •

Paul Ferrero, who is Swiss, is a graduate of chemical engineering from the University of Geneva. After two years in the dyes industry in Paris, he returned to Geneva as a member of the University staff. In 1929, Dr. Ferrero took over the direction of the industrial group researches of Société Carbochimique and Société Carbonisation Centrale at Tertre, Belgium. Under his direction in research, new developments were made on the production of ethylene and propylene oxides from coal tar gases and on improvements of dyes in the Belgium chemical industry. From 1951-53 he was president of the Chemical Society of Belgium and in 1954 was made an honorary member of the Industrial Chemical Society of France.

• • •

N. N. Melnikov

V. B. Aleskovskij

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Valentin B. Aleskovskij was born in Mary, Turkmen Republic. He is a professor at the Technological Institute, Leningrad. He is the author of a number of scientific articles for the Soviet press.

The Chemical Industry in Western Germany

PROF. DR. K. WINNACKER,

President, Farbwerke Hoechst, A.-G.,
Frankfurt, West Germany

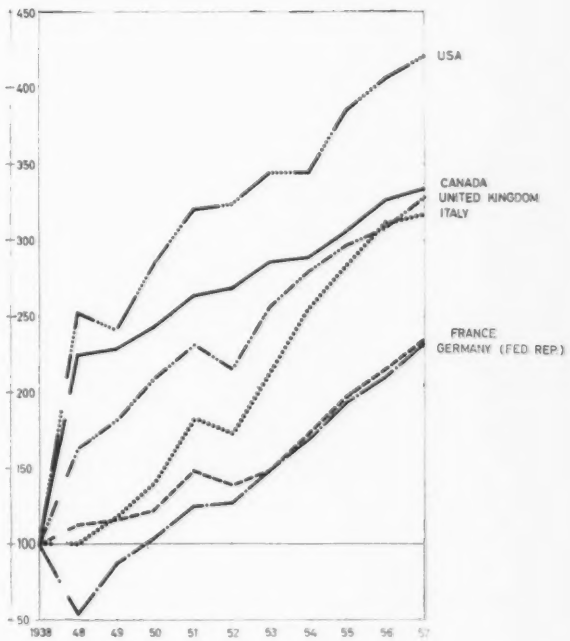
It was with great pleasure that I accepted your kind invitation to talk to you about West Germany's chemical industry. I am a chemist by profession and my review of the present state of West Germany's chemical industry will therefore be chiefly concerned with techno-economical aspects. I will also try to discuss the raw material position but I shall avoid a discussion of trade questions as I do not feel quite competent in this field.

The collapse in 1945 completely paralyzed our whole economic system, including, of course, chemical industry. Our task in the immediate post-war years, therefore, was to bring back into production the destroyed, dismantled or closed-down plants. In this task, the separation of the highly developed industry of the Eastern zone, an integral part of our economy, presented problems that even today are not easily understood by people abroad.

The figures used here are taken from the official OEEC statistics and show the development of the chemical industry in certain countries since the end of the war. I should emphasize that this is a random selection. The statistical material is incomplete and the order in which the countries appear is not intended in any way to reflect their importance. These few statistical comparisons are intended solely to illustrate the relationship between West Germany's chemical industry and that of competitor countries.

Taking chemical production in West Germany in 1938 as 100, in Figure 1, the comparable figure for 1957 was 230. At the end of the war the figure sank very low, not surpassing the 1938 figure until 1950. Countries like Italy, Great Britain and above all, Canada during the same period reached an index figure of 300-350 while the United States achieved a fourfold increase of its chemical production during these 19 years. In 1938 the area of Germany corresponding to the present Federal Republic of Germany produced 15% of the value of the world's chemical output. Our share today is about 6%. If, in assessing the development of our chemical industry, due allowance is made for the relatively short periods of time involved, it can be stated that in recent years our rate of expansion has reached that of other countries.

Figure 2 illustrates the same relationships, but in a different form, for the years 1938 and 1956. The figures for the Eastern zone, taken from official statistics, are also included but, of course, all my comments refer to conditions in Western Germany. It should be noted in



1938		Production of of Chemical Industries	1955		1956	
Billions of Dollars	%		Billions of Dollars	%	Billions of Dollars	%
10.8		World	56.0		59.0	
1.6	14.8	Germany (Fed. Rep.)	3.4	6.1	3.7	6.3
3.2	29.7	U.S.A.	23.0	41.1	24.2	41.0
0.9	8.3	United Kingdom	5.0	8.9	5.2	8.8
0.6	5.6	France	2.3	4.1	2.6	4.4
0.4	3.7	Italy	1.7	3.0	2.0	3.4
0.15	1.4	Canada	1.0	1.8	1.1	1.9

Figure 1—Indices of production in chemical industries according to OEEC; 1938 = 100.

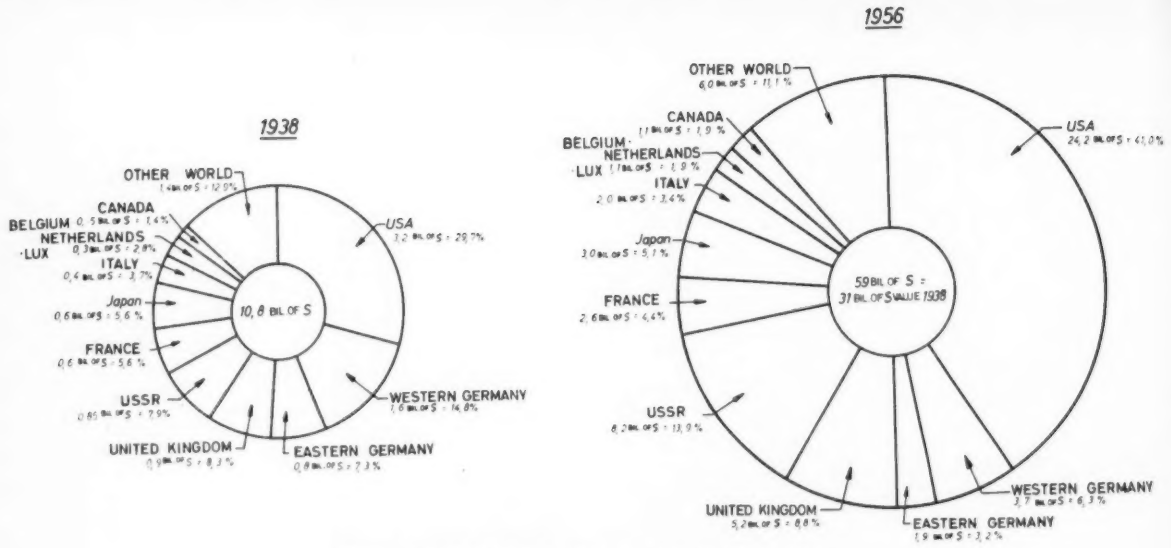


Figure 2—World production in chemical industries.

this diagram that the value of world chemical production, 59 billion dollars in 1956, corresponds to a 1938 value of only 31 billion dollars. (Billion is used instead of 1000 million). Taking 1938 as 100 this means that in 1956 the average world price index for all chemical products was 190, (remembering, of course, that this cannot be a very exact figure). In Western Germany this price trend is peculiar to the chemical industry, for while the mean price index of all chemical products is around 190, the index of *all* industrial products is around 230. The price index of our industrial raw materials is 260, that of coal as high as 350 and that of iron and steel even 360. It must be stressed that these are, of course, the raw materials that have a particularly great influence on the prime costs of the products of chemical industry.

Also during the past five years prices for chemical products tended to decrease. For instance, in our company, Farbwerke Hoechst, the total of all prices since 1952 has been reduced by more than 10%. This price development reflects the great achievement of the chemical industry, not only in Germany but more or less throughout the world.

Chemical industry is one of the most modern branches of industry. Mainly because of its intensive research and development effort, it is in a position to continuously rationalize processes and to improve and perfect them in such a way that increased investments and rising cost of power and social services can be largely absorbed. Thus, by lowering prices, chemical industry is making a major contribution towards improved living standards.

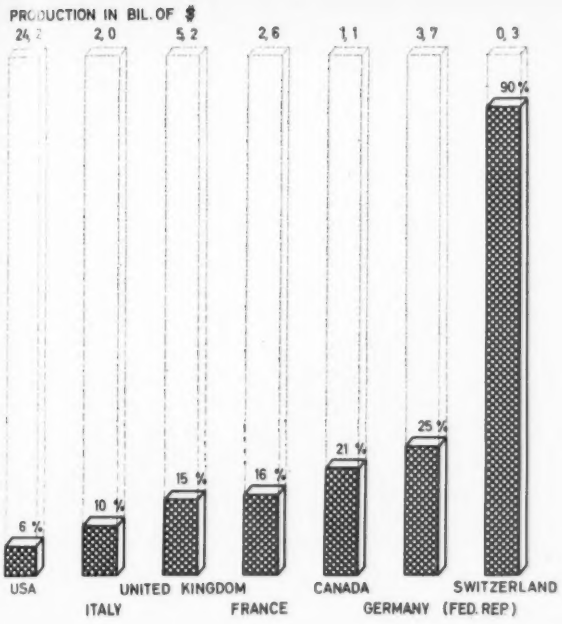
To summarize, Figure 2 shows that in 1956 West Germany's chemical industry was the fourth-largest producer, preceded by the U.S.A., Russia and Great Britain. The picture is different, however, if instead of total chemical production, the share in world chemical trade is considered.

In 1956 Western Germany occupied second place in world chemical trade, with the U.S.A. first and Great Britain third as is shown in Figure 3. At present 25% of West German chemical production is exported. This relatively large export share represents, however, barely 15% of total world chemical trade and is thus considerably lower than, for instance, that of the United States whose share is 24%, although it exports only six % of its much larger production. This is a very important feature of the German chemical industry. It is very largely geared for exports and therefore all the more dependent on free exchange of goods without customs and foreign exchange restrictions. Fluctuations in chemical world market conditions caused by relatively small export increases from other countries, for instance America, could quickly and severely hit the German chemical industry because of its relatively high export ratio. This could have severe consequences on the activity of West Germany's chemical industry. On the other hand, of course, West Germany's export ratio is greatly exceeded by that of Switzerland which sends abroad 90% of its chemical production, accounting for 4% of world chemical trade.

The future common market and the free trade area will naturally reduce the export risk of our chemical industry. About a quarter of West German chemical exports go to member states of the common market and half of it to West European countries of the future free trade area. The export share of our chemical industry's total turnover would, therefore, be reduced from 25% to about 10%. This would approximate conditions in the U.S.A. and should render Western Europe much less sensitive to fluctuations in export trade.

In 1956 the overall production of West German industry was worth approximately 185 billion marks. Out of this figure, the chemical industry accounted for 15.4 billion marks, that is 8.3% of the entire production. It occupies third place, being preceded by the food and beverage industry with approximately 15% and the machinery industry with approximately 9%. The textile industry, one of the most important users of chemical products, occupies fourth place with a good 7%. In the last few years the chemical industry has expanded at a greater rate than any of the other industries so that it may be assumed it will soon again account for 10% of West Germany's entire industrial output.

Figure 4 shows in what percentages German chemical production is distributed over various product groups. This purely statistical summary does not express adequately the peculiarities of this distribution which is based partly on historical factors and partly on the raw material situation. Let me discuss a few of these factors typical of development in Germany without making any claim to



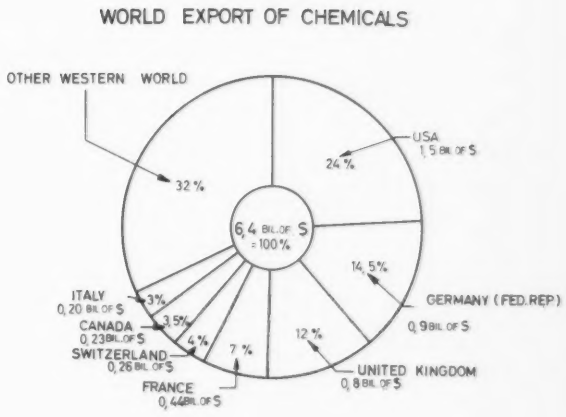


Figure 3—Chemical export quotas of selected countries in percentage of the production in 1956.

giving a complete picture. The coal tar dyes have dictated the course of the chemical industry to a far greater extent than is shown by this Figure. For instance, around 1860, coal tar dyes were the reason for the foundation of such internationally famous chemical concerns as Bayer Leverkusen, Badische Anilin- & Soda-Fabrik, Farbwerke Hoechst, Kalle, Cassella Mainkur, etc. Even today, coal tar dyes, in some respects, play an important part in the production programs of these companies. Organic synthetic chemistry, which achieved its first major victory with the development of coal tar dyes and the requisite starting and intermediate products, has exercised a decisive influence on the whole of scientific and technological developments. Its methods have, to this day, determined the character of West German chemical industry. At the end of the last century the successful coal tar dyes were joined by the synthetic pharmaceuticals. Based on the same organic-synthetic chemistry and, of course, promoted by the great progress in medicine and biology, the first chemotherapeutic drugs of great fame were developed. Not only was their production closely allied to that of the coal tar dyes, but they also required the same starting products. Coal tar dyes and chemotherapeutic drugs, together with their starting and intermediate products, occupied a major place in the production program of the large German chemical companies. And although the antibiotics of the last 15 years have made such a wonderful contribution to our range of pharmaceuticals, synthetic chemistry and chemotherapy are still playing a particularly important part also in the new developments of the German pharmaceuticals industry. Systematic and painstaking laboratory work in classical inorganic and organic chemistry which paves the way for large-scale production, has remained a characteristic of German industrial development of insecticides and pesticides and textile auxiliaries right up to the present time, the age of plastics and synthetic fibres.

In the renewed vivid exchange of ideas with our foreign colleagues we often get the impression that these German research methods are characteristic of our way of thought. These methods and this approach primarily directed to experimental work are also evident in the

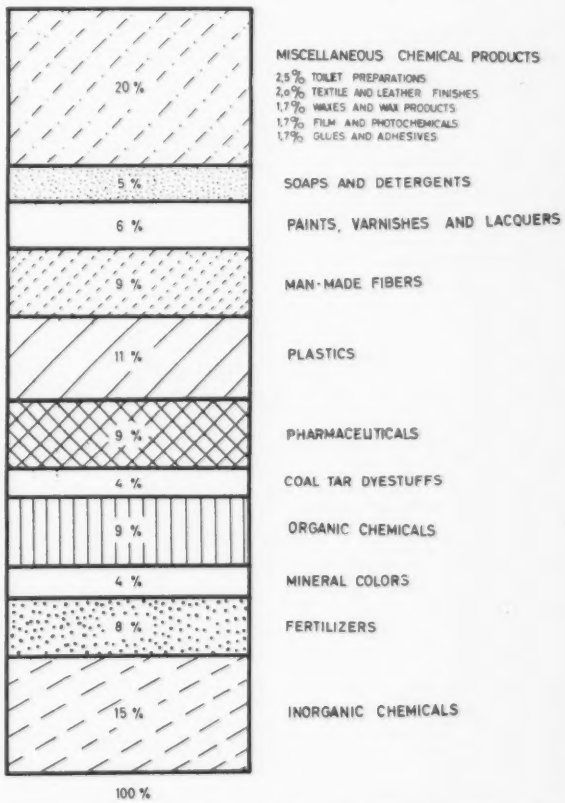


Figure 4—Structure of the chemical production of Germany (Fed. Rep.)—average production 1952-56 = 11.7 billion of DM.

activity of our universities and research centres. Research and industry have stimulated each other. This approach still plays a big part in the training of our chemists. Of course, our chemistry could not be divorced from physics

TABLE 1

WESTERN GERMAN CHEMICAL COMPANIES TOTAL TURNOVER IN 1956

	mil. of US $			mil. of DM
Farbenfabriken Bayer Ag.	380			1,596
Badische Anilin-& Soda-Fabrik Ag.	357			1,498
Farbwerke Hoechst Ag.	353			1,482
	1,090	= 30%	=	4,576
18 Companies with yearly sales between 500 and 100 millions of DM	1,085	— 30%	—	4,553
Other 3,100 companies	1,500	— 40%	—	6,305
	3,675	= 100%	=	15,434

TABLE 2

SELECTED FIGURES OF CONSUMPTION AND PRODUCTION IN THE FEDERAL REPUBLIC OF GERMANY 1956

	Consumption Thousand Metric Tons	Production Thousand Metric Tons	Production in % of Consumption
Iron Ore	36,797	16,928	46
Nickel Ore	20	–	–
Copper Ore	173	10	6
Chrome Ore	218	–	–
Bauxite	1,317	5	–
Pyrites	1,966	644	33
Sulphur	63	–	–
Phosphate Rock	904	–	–
Pulp Wood (in 1000 cbm)	6,325	4,268	67
Lumber (in 1000 cbm)	9,105	7,043	77
Cellulose	1,701	1,275	75
Rock-Salt	3,075	3,581	116
Potash	15,461	15,544	101
Crude Petroleum	11,505	3,506	30
Hard Coal in bil. metr. tons	162	166	103
Lignite only	32	32	100
Electric Power bil. KWH	85	84	98
Hydro only	–	13	–

and physical chemistry, to which it has made a significant contribution. But characteristic differences as, for instance, the conception of the position of the chemical engineer, which we do not know in Germany in its English sense, go back to these early traditions.

The decisive historical influence of the chemistry of coal tar dyes has also left its mark on the economical and legal structure of the German chemical industry. The necessity to rationalize and to concentrate the coal tar dyes industry was the impetus for the formation of the I. G. Farbenindustrie which, however, largely outgrew its inital tasks during the 20 years of its existence.

Table 1 shows the structure of the West German chemical industry according to size of companies. The supremacy of the former I. G. Farbenindustrie no longer exists, particularly since more than half of its assets and factories were lost in Eastern Germany and abroad. The three big chemical companies which were reconstituted after the dismemberment of the I.G., namely, Bayer in Leverkusen, Badische Anilin- & Soda-Fabrik in Ludwigshafen, and Farbwerke Hoechst in Hochst have now grown far beyond their original field of coal tar dyes. During their more than 90 years of existence the three companies had been linked together in one concern for only 20 years. For the last 13 years each has again pursued its own course in all branches of modern chemistry. The coal tar dyestuffs, the old connecting link, are no longer a sufficient reason for a closer association. It may, therefore, be said that 30% of German chemical output is produced by three companies with independent business policies in Germany and abroad, now and in the future.

Table 1 shows that another 30% of German sales in chemicals is accounted for by 18 big companies whose sales vary between 100 and 500 million DM. Among them, working in various chemical fields, are concerns rich in tradition and known all over the world, such as the Deutsche Gold-und Silberscheideanstalt, Merck, Chemische Werke Huls and, in the textile fibre sector, Vereinighte Glanzstoff-Fabriken. These names are mentioned only by way of example and without any intention of indicating importance.

The remaining 40% of German chemical sales is spread over 3,100 smaller chemical firms. Among these are many very active companies of great importance, for instance, in plastics production, the pharmaceutical industry, the paint, varnish and lacquer industries, and a large number of special chemical products.

To summarize, therefore, let me emphasize again that there can be no question whatever of the market being dominated by group of individual Companies. On the contrary, there is, a very healthy ratio between big, medium-sized and small companies and this makes, of course, for sound competition.

The German chemical industry—mainly, but not exclusively the large companies—developed on the basis of coal. The chemical industry, therefore, had its beginning in the Rhine and Rhur areas and around the network of waterways connected with them. At a later date, it also developed in Silesia from which we are now separated. Highly developed techniques of coal processing supplied industry, at an early date, with coal tar and its various distillation products. Based on coal tar, the production of aromatic hydrocarbons was developed next. These hydrocarbons furnished the organo-synthetic dyestuffs and pharmaceuticals industries with their starting materials. Even today the manufacture of pure, highly condensed cyclic systems, not previously isolated, at times sets in train entirely new developments. A wide network of gas mains connects the big chemical plants to the gas supply from the coke ovens. The Saar territory also forms part of this system. The close association between the coal and steel industries has given rise to production of gas which supplies not only energy to the chemical industry but has also become the basis of operations for the production of industrial gases in a large number of nitrogen and similar plants.

This traditional basic raw material of the German chemical industry is, however, becoming more and more endangered in respect of quantities and, particularly cost. The mining of coal is growing more difficult because seams lie deeper and are lower-grade. On the other hand,

mining wages are rising. In the light of the price increases of recent years, coal, even today, no longer seems competitive for many tasks in our branch of industry. In particular, we do not think that there are any great prospects for economic expansion of the electrochemical industry in Germany as long as we have to stick to coal as the raw material basis.

This situation, however, has been alleviated by the German lignite. In the region of Cologne, but particularly in Central Germany, to the north of Leipzig, there are large deposits of lignite; these furnished the basis for an electrochemical industry which in the first decades of its existence was really competitive. These deposits of lignite became another important raw material basis for the chemical industry. In consequence of the political events the Central German lignite can no longer be reckoned upon. The West German lignite, however, which is of higher quality, will come to an end before long. Today it is estimated that, with present mining methods continuing, it can meet the requirements for 20-30 more years. Larger supplies can be opened up only at considerably higher cost. The deposits in Central Germany, although of lower quality, are still larger.

Hydraulic power was also employed early for energy production, especially in Southern Germany. Today, of the total West German electrical power production, amounting to about 85 billion kWh, only about 15% stems from hydraulic power stations. Moreover, hydroelectricity can no longer be greatly expanded, or only at very high cost. Atomic energy will therefore also become a vital question for the chemical industry in Germany. Conditions for utilization of atomic energy in Western Germany, however, are not favorable from the viewpoint of raw materials. In particular, we shall have to rely on the supply of uranium minerals from other countries.

German production of petroleum is already no longer sufficient to meet all requirements. Hardly 30% of the necessary amounts can be supplied from German sources. The production of natural gas amounts to 400 million cu.m. This is 8% of the present Italian production of this raw material, which in turn is about 1.5% of the production in the U.S.A. Nevertheless, natural gas is of interest for the chemical industry in Germany. We hope that it will be possible to reserve a large part of the natural gas sources so far discovered for chemical purposes. Considering its scarcity, methane is much too valuable a chemical raw material to be used as a heat source only.

The consequence of this overall situation in the fields of coal and petroleum is that a further increase of energy production in Western Germany will be difficult and expensive. This will entail important consequences for the chemical industry. Production of aluminium and ferro-alloys is still possible only where old sources of power are available at a favorable price. Other branches of industry, such as production of magnesium, will soon have to employ power-saving methods.

In Table 2 we have tried to show several basic raw materials of the chemical industry of Western Germany in such a way that it can easily be seen which materials are available in Germany in adequate supply. It is obvious at a glance that only a few raw materials, including energy, are available in adequate amounts. In the case of coal and power, where the picture, for the time being, still seems favorable, the necessary proviso as to cost has already been mentioned. As regards coal, it should be further said that under the terms of the European Coal and Steel Community, the Federal Republic of Germany is obliged to export a quota of coal so that part of the German requirements have to be met by imports. In the case of petroleum, the quantitative deficiency in the country is evident, and in the next few years the consumption of petroleum is likely to increase more rapidly than the German production.

Wood, as raw material, is available in the country in sufficient quantity to meet 70 to 75% of domestic requirements. The situation as to cellulose is similar; about 25% of the consumption has to be imported to meet requirements for the manufacture of regenerated cellulose fibres, Cellophane etc., and also of paper. Raw material supplies are favorable in the case of rock salt. As is well known, a big German industry of alkali chloride electrolysis has been developed on the basis of electrical power and salt. This is being vigorously expanded because the demand for chlorine, and to a lesser extent that for caustic soda, continues to increase. Let me mention the greatly increasing demand for chlorinated organic solvents, for chlorinated hydrocarbons for synthetic plastics and for numerous other halogenated chemicals for refrigerants, propellent gases, pesticides, etc.

In the case of potassium salts, too, the situation may still be regarded as favorable, although Germany's former leading position has been lost because of the loss of the central German salt deposits. In Germany, the potassium salts are the foundation of a big industry, rich in technical tradition.

All the raw materials for production of metals are scarce in our country. One must not be misled by the statistical figure for the output of iron ore because it includes a considerable portion of low-grade iron ores which can be smelted only at high cost. As regards nickel, copper, chromium, aluminium ores, and phosphates, large amounts have to be imported so that the chemo-metallurgical industry can operate profitably only when the final products obtained have a high commercial value.

A characteristic feature of the West German chemical industry is the close connection between the sulphuric acid industry and the production of metals from pyrite.

Almost the entire German sulphuric acid industry—which has always been a barometer of chemical activity—has hitherto been based on pyrite. Two-thirds of the pyrite requirement, however, have to be imported. As a result of a development spanning several decades, the big German producers of sulphuric acid have become closely associated with their copper smelting works. In the case of the *Duisburger Kupferhütte*, this co-operation has reached a particularly high technical level of rationalization and perfection and has exercised a very favorable effect on both the metal markets and the price of sulphur.

Owing to this highly developed special industry, the Federal Republic of Germany has achieved a significant production of copper, zinc, lead, cobalt and of precious metals, such as silver etc.

The opening-up of the large sulphur deposits in Mexico, and especially the increasingly important sulphur production at Lacq in southwestern France, where there is a large source of natural gas, are now endangering this industry which has functioned so successfully from an economic point of view. In other industrial countries, for instance, the U.S.A. and Great Britain, the sulphuric acid industry has in the past few decades changed more and more from the processing of pyrite to the combustion of elementary sulphur. Technically, this would, of course, also be possible for the West German sulphuric acid industry. But in view of the downward trend of metal prices, this might, in the midst of the chemical boom, create an entirely new economic situation for the sulphuric acid industry.

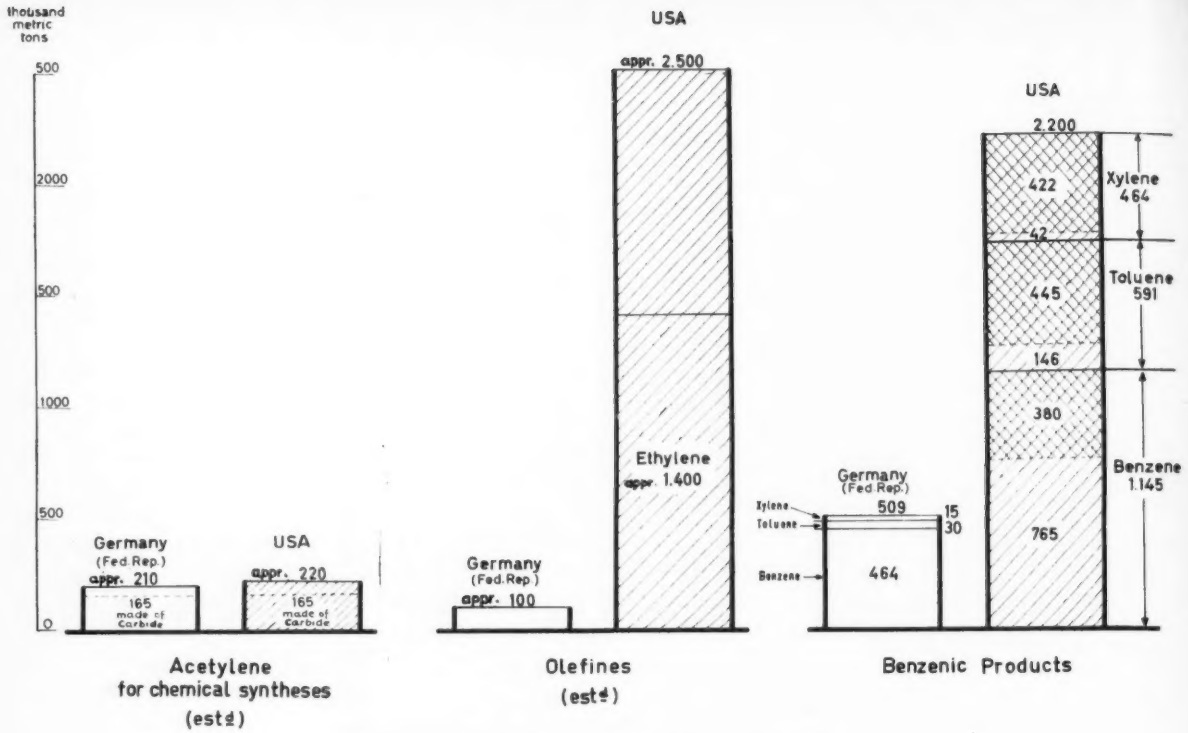


Figure 5—Production in 1956; thousand metric tons.

To summarize, it may be said that, owing to the raw material situation, the German chemical industry has not really a secure basis. It depends to a high degree on supplies from abroad and will maintain its ability to meet competition only if it continues to turn out highly developed products which require much processing, so that their prime cost is not much affected by the price of the raw material used.

Whereas coal, as the most important raw material, had so far been available in sufficient amounts, a new situation has arisen in the West German chemical industry during the last 10 years because of the rapid development of plastics and their preliminary products of synthetic rubber and of the man-made fibres.

Hydrocarbons from coal, up to 1945, constituted almost the sole basis for our chemical industry. Now, they are no longer sufficient in respect of either quantity or cost. Therefore, in Germany too, the necessity has arisen to change over to the production of hydrocarbons from petroleum.

An interesting example of the different ways in which the transition from coal to petroleum has proceeded is provided by a comparison between the production of the most important organic raw materials in West Germany and in the U.S.A.

Figure 5 shows such a comparison. You will see that in Germany production of acetylene for chemical processing, mainly by the classic calcium carbide method, that is to say from coal, is comparable to that of the U.S.A. which in other fields has a far superior output. German acetylene production, to which historically the large, now lost, carbide production of central Germany must be added, was at first adequate for the West German plastics industry. The German Buna synthesis which reached an output of 200,000 tons per annum, was built up almost exclusively on this acetylene basis. After 1945, however, changes were necessary and because of the increase in price of energy and coal, acetylene from carbide is not likely to have much of a future from an economic point of view.

This Figure 5 shows clearly the part played in the U.S.A. by the olefines, particularly ethylene, in the supply of raw materials for modern organic chemistry. In recent years olefine chemistry has also considerably expanded in Germany, but the lead of the U.S.A., as you will see from the diagram, is enormous. It is, however, certain that the volume of olefine production will increase rapidly in Germany as well as in other countries.

Up to the present the supply of aromatics based on coal is sufficient. Production based on petrochemicals does not, as yet, exist and it is probable that there will be no vital changes in the near future, unless special derivatives such as p-xylene demand such a development. In the U.S.A. increasing amounts of aromatics, particularly the higher ones, are being produced from petroleum.

The pressure hydrogenation of coal by the I.G. process and the petrol synthesis according to Fischer-Tropsch, which operated in Germany during the days of self-sufficiency, have not proved themselves under conditions of free world competition, at any rate not in Western Germany. However, the technical know-how gained in the operation of these processes has been of great value in the rational processing of petroleum and has proved very helpful in the launching of Western Germany's petrochemical industry.

Conditions for industrial petrochemistry—a term with which you will all be familiar—were unfavorable at first in Western Germany. For one thing, the capacities of the existing petroleum refineries were relatively small so that profitable association with a chemical concern for

the conversion of the refinery waste gases could not be realized in all potential cases. Moreover, the geographical location of the large chemical production centres operated against the use of refinery gases because there were no refineries near them. Nor was it practicable to think in terms of moving these industries because in the densely populated territory of West Germany the movement of a large number of people would be very difficult, to say nothing of the cost of such a transfer of the people, or the human and social problems that it would raise. Sources of natural gas so far discovered in Western Germany are of interest but not yet adequate to support large-scale petrochemical plants. Technically, the conversion of methane into chemical reactive olefines presents no difficulties.

In view of this situation, the West German chemical industry, apart from adopting foreign processes, also developed special methods for the production of olefines. These special methods, however, could be developed only within the limitations imposed by local conditions. Farbwerke Hoechst have, in recent years, set up such a type of special petroleum refinery at Frankfurt-Hoechst. Our large-scale chemical plant, for a variety of reasons, needs access to petrochemicals and it is, therefore, a consumer of almost all products supplied by our special refinery.

Figure 6 describes the operation of this refinery. In a normal topping plant the lighter petroleum fractions are separated from the heavy ones. From the former, acetylene and ethylene are then prepared in a new-type cracking process—hydrogen, methane and carbon monoxide—are returned to the plant and used in the production of the required high temperatures. The heavy petroleum fractions from the topping plant are introduced into the Hoechst continuous cracking process where they are cracked into ethylene, propylene and olefinic C4 fractions by the action of hot circulating coke pebbles. The saturated C_2 and C_3 hydrocarbons formed at the same time are also transformed into ethylene and propylene by means of a parallel medium temperature pyrolysis. The residual gases, methane and hydrogen, serve as a basis for the synthesis of ammonia, while the coke is utilized in Farbwerke Hoechst's electrode-plant.

This process, therefore, does not provide petroleum products for the fuel and fuel oil markets. Chemical industry is thus not compelled to enter extraneous markets with fuel, lubricants or fuel oil. This plant is an example of how petrochemical processes can make it possible to provide a sound raw material basis independent of geographical factors and of the proximity to large refineries. The Hoechst process enables old-established plants to introduce petroleum and hydrocarbon fractions into the manufacture of intermediates for dyestuffs, textile auxiliaries and particularly plastic and man-made fibres.

It must be emphasized that this special type of refinery requires thorough examination of all the economical factors involved. This method is almost certainly not easily applicable to every set of conditions. If larger refineries are going to be erected in Germany, it will no doubt be possible to achieve the same close co-operation between the petroleum and the chemical industries as has already been realized so successfully in other countries.

The manufacture of plastics, which in Germany started at an early date, has expanded considerably in recent years.

These developments are presented in Figure 7. The left hand side shows the total output of plastics. You will see that in the last 20 years production has increased tenfold and that the polymerization products show a particularly high rate of expansion. This has also been

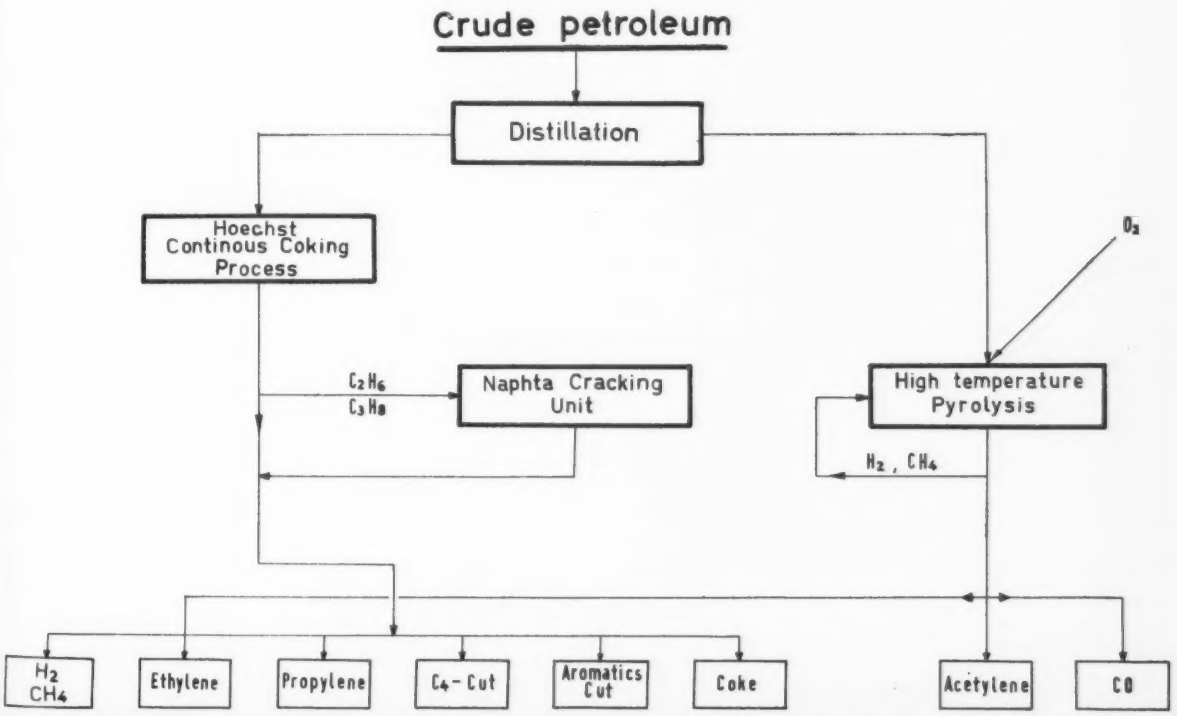


Figure 6—Flow-sheet shows operation of special petroleum refinery.

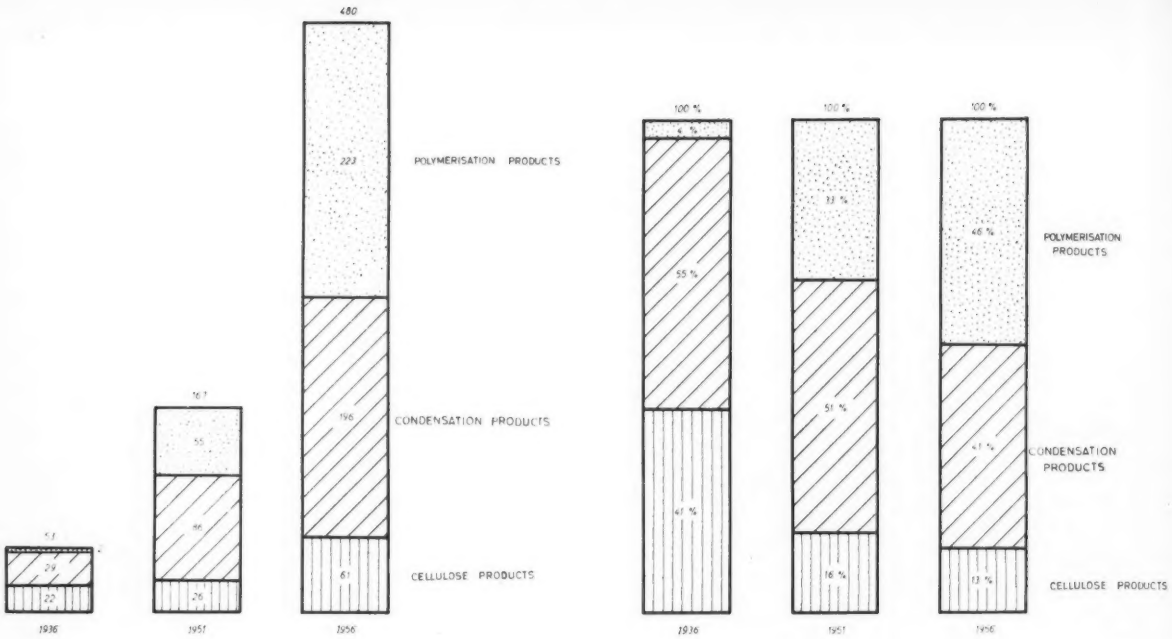


Figure 7—Production of plastics in Germany (Fed. Rep.) in thousand metric tons.

observed in other countries. On the right, you will see how the share of polymerization products has risen from an initial 4% to 46% of total production. The development of this type of plastics is likely to continue even if recently condensation products have again made considerable strides.

Figure 8 shows that West German plastics production per head of the population has rapidly caught up on the United States.

Apart from high-pressure polyethylene, the low-pressure polyethylenes and polypropylenes are gaining considerably in importance among the polymerization products which include, of course, the classic vinyl products such as vinyl acetate and vinyl chloride. Since Ziegler invented the process in the Muhlheim laboratory, it has been developed to the point of large-scale manufacture in Western Germany. We have great hopes of polyethylene and particularly polypropylene.

In contrast to the vigorous development of plastics production, the consumption of textile fibres and therefore their production and import has, during the same period of time, not increased significantly, as shown in Figure 9. Noteworthy is only the relative decrease in the consumption of natural fibres and the steady increase in the production of man-made fibres. If we leave aside regenerated cellulose fibres, which are giving rise to some concern because of the intense international competition, the outstanding feature of the last few years has been the growth of fully-synthetic fibres. The delay in the development of large-scale production was dictated by political factors. Although Perlon, made by the polymerization of Caprolactam, was discovered in 1938, the war delayed its development and it was fully 12 years before large-scale production got underway. Because of our own polymerization developments, the manufacture of Nylon 66 was retarded much longer. Polyacrylonitrile production, for the Buna synthesis for example, had been known since 1935. In this field, too, the war and post-war conditions greatly hampered progress. The manufacture of polyester-fibre was begun in 1956. It will be readily understood that Germany, normally so receptive to chemical novelties, had in these hard years other needs than these high-grade textile fibres which, after all, imply a certain standard of living, if not luxury.

This interesting and wide field still holds many challenges for chemistry. The development of man-made fibres, after some initial successes, was accompanied by many reverses. This again illustrates that the way from the laboratory to the complex textile industry and thence to the user is fraught with difficulties and prejudices. Nevertheless, we are confident that man-made fibres have a great future because of their unique properties and their chemical versatility, since, in their manufacture, the great efficiency of chemical technology will again be in evidence, demonstrating that progressive improvement of processes leads to a more economic and therefore cheaper production which is, moreover, independent of bad harvests or other seasonal fluctuations. We consider it as our chief aim, at present, to effect a thorough improvement of dyeing and processing methods, for on the success of this endeavor will depend the ability to stay competitive in the field of mass-produced articles.

If we ask ourselves what the immediate future holds for the West German chemical industry, we must remember that much depends on the extent to which we can rationalize our productive methods. The impending economic fusion of Western Europe to a larger common market or a free trade area, offers tremendous opportunities. These can be exploited only if progressive automation and full utilization of all resources are marshalled to achieve the highest degree of production efficiency. Large markets make the realization of such aims possible. Conditions in the U.S.A., where turnover of chemicals per head of population is much higher than in Western Germany at present, show that it is possible to increase

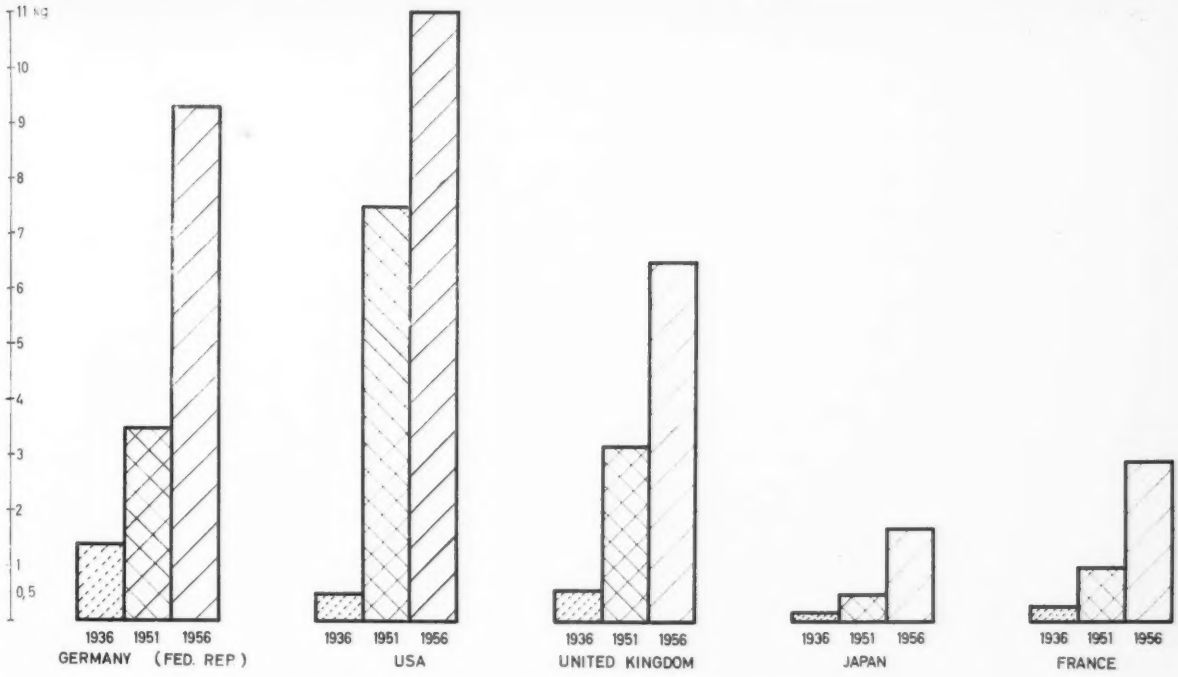


Figure 8—Per capita production of plastics in selected countries.

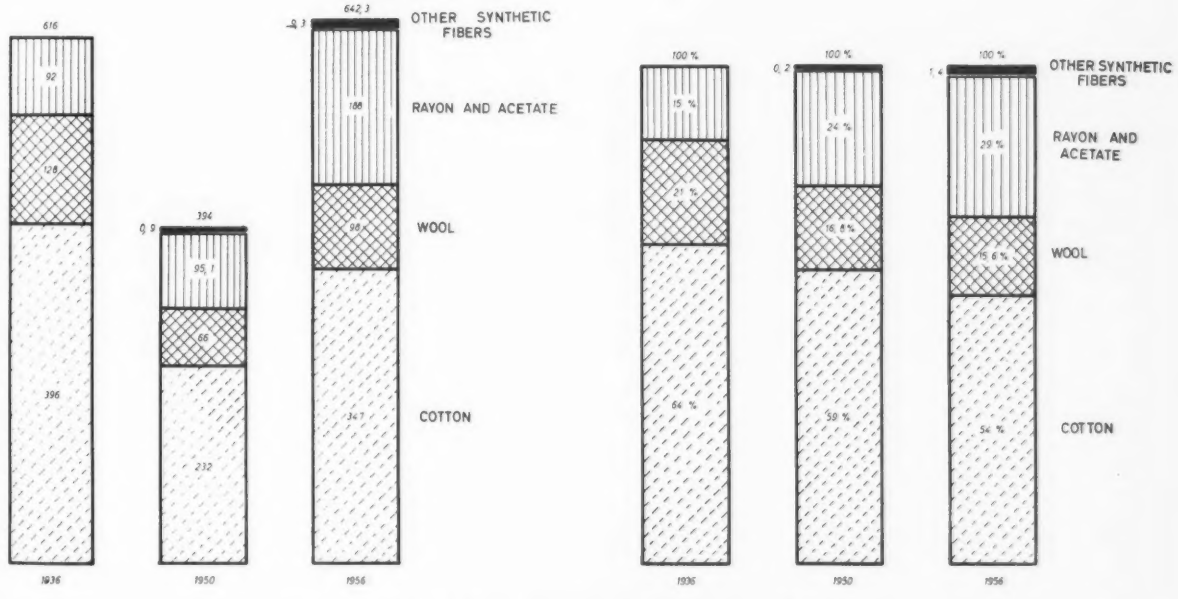


Figure 9—Textile fibre consumption in Germany (Fed. Rep.).

production even with a relatively smaller labor force. We shall, therefore, increase the as yet lagging productivity of our plants.

Future scientific and technical development is with us, too, a question of manpower. Because of the scale and pace of our post-war reconstruction, so that our industrial production could again match that of our neighbors, there is in West Germany today full employment. There are in the Federal Republic, apart from seasonal variations, no unemployed. But this, in itself, happy state of affairs also has important and expensive consequences. Labor is in short supply and therefore expensive. The legend of Germany's low wages has been finally exploded in the last two years. Shorter working hours and the large

number of old and sick employees have greatly increased the cost of social services. We shall be able to stay competitive in the chemical industry only if we continuously rationalize our production so as to compensate for the lack of raw materials and manpower.

I hope that I have shown you some of the main features that have characterized the development of West German chemical industry during recent years. I would like to conclude by spot-lighting a need that, in my view, applies equally to the chemical industry of every country: science and chemical technology will prosper only if they are allowed to develop independent of national frontiers and without state interference. Free exchange of views and free trade between nations are essential prerequisites of technical progress. The German chemical industry is looking forward with eager expectation, to the development of the European Common Market which, though it will involve great sacrifices, may confer the greatest benefits on all its members. We hope that this wider common basis of trade will, in turn, lead to unfettered and successful co-operation with other trade areas.

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The Chemical Industry in the United Kingdom

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To do justice in the course of about an hour to such a wide subject as the chemical industry of the United Kingdom is quite a formidable task and, when I came to prepare this paper, I quickly realised that I had only two choices. The first was to try to cover in strict fairness the whole field of chemical development which would inevitably have resulted in a dreary catalogue of facts and figures. The second was to concentrate on those parts of the industry which, perhaps with some personal bias, I feel have shown the most interesting progress in recent years. I decided on the second choice and, being originally a cross between an organic chemist and a petroleum technologist, it is perhaps natural that I propose to devote much of this paper to the spectacular growth of the organic side of the industry with special emphasis on the provision of its raw materials

To begin with however I should say something about the industry as a whole, its size, its importance in the British economy and its growth in recent years. The most readily available statistics provided by the Board of Trade and other Government Departments unfortunately refer to the chemical and related industries in combination and therefore include coal carbonisation and by-product activities, mineral oil refining and many compounding and formulating operations. Using this broad definition the turnover in U.K. produced chemical products amounts at present to almost exactly 10% of the total value of all British manufactured products, and it is of the same order as that of the motor vehicle and the textile industries. The only two industrial groups with a higher turnover are those covering firstly the combined engineering, shipbuilding and electrical industries and secondly all food manufacturing operations. As shown in Table 1 the index of production by the chemical and allied trades has increased by 85% between 1948 and 1956, that is by an average of roughly 8% per annum. This is almost double the rate of increase for British industry in general. Over the same period the value of chemical production increased from £732,000,000 to £1,998,000,000 or by 13.5% per annum.

It is interesting to note that this increased production was achieved with only a 2% per annum increase in personnel employed and that the net output of the industry, that is the value of gross production less cost of materials and of fuels corresponded in 1956 to £1,470 per person directly employed. This productivity per person was some 50% higher than the average for British industry in general and reflects the high degree of mechanisation and instrumentation of the modern chemical industry.

The rapid expansion of production and the achievement of this high productivity have involved very considerable capital expenditure, totalling some £780,000,000 during the period 1948 to 1956.

In 1949 and 1953 the Association of British Chemical Manufacturers published excellent reports covering the progress of the British chemical industry up to and including the year 1952. In these surveys they adopted a much narrower and more useful definition of chemical industry, leaving out coal carbonisation, tar distillation, mineral oil refining and the formulating industries such as those concerned with the manufacture of paints, insecticidal sprays and medicinal compounds. No official figures for years subsequent to 1952 are yet to hand but, by analysis of a good deal of published and unpublished data, I have been able to make rough estimates which I think are sufficiently accurate for our present purpose. These estimates together with the published A.B.C.M. figures are shown in Table 2.

The chemical industry proper as defined by the A.B.C.M. is relatively highly concentrated. It covers less than 300 manufacturing firms compared with some 2,200 concerns involved in the whole of the chemical and allied trades. Moreover about 80% of its operatives are engaged by only 20 or so companies each employing more than 1,000 people. In turnover, number of people employed and capital expenditure, the chemical industry proper nevertheless accounts for 40 to 50% of the activities in the whole chemical and allied field. Its turnover has increased by an average of 12% per annum between 1948 and 1956, this being accompanied by only 1.7% per annum increase in the number of payroll operatives. There has, however, been a very marked increase from 6,176 to 9,500 in the number of scientifically qualified staff and it is noteworthy that as much as 65% of this is attributable to increased attention to the scientific side of design, manufacturing and sales operations as distinct from research and development. In addition, of course, research and development has played a great part in the growing activity of the chemical industry and I estimate that in 1956 the total expenditure on these activities in the chemical industry as defined by A.B.C.M. reached £19,000,000 to £20,000,000.

It will also be seen from Table 2 that the chemical industry makes a very considerable contribution to British exports. In 1956 export of chemicals as defined by the A.B.C.M. had a value of approximately £200,000,000 representing roughly a quarter of the total U.K. chemical production.

The recent increase of some 13% to 14% per annum in the turnover of the U.K. chemical industry is an

TABLE 1

CHEMICAL AND ALLIED TRADES

	1948	1949	1950	1951	1952	1953	1954	1955	1956	% increase per annum
Index of Production	100	108.9	124.2	134.8	133.3	152.9	168.5	178.5	185.1	8.0
Index of Production (all U.K. manufacturing industries for comparison)	100	106.8	115.8	120.6	115.6	123.2	133.2	141.9	139.9	4.3
Value of Products. £M	732	–	–	1248	1342	1427	1687	1882	1998	13.5
Net Output (gross production less cost of materials and fuels). £M	259	261	–	362	367	416	529	583	613	11.3
Net Output per Person Employed. £	766	–	–	960	959	1093	1320	1390	1470	8.5
Net Output per Person Employed (all U.K. manufacturing industries for comparison). £	561	–	–	677	687	736	810	860	900	6.1
Total Employment in Chemical & Allied Industries (thousands)	350	–	–	387	393	390	405	419	417	2.2
Annual Capital Expenditure. £M	39	60	86	104	107	110	89	96	130	16.2

TABLE 2

COMPARISON OF 1948 AND 1952 A.B.C.M. DATA WITH ESTIMATED DATA FOR 1956

	1948	1952	1956	% increase per annum
Production:				
Annual value £M	323	520	810	12.1
Employment:				
(a) Total	141,817	151,349	175,000	2.7
(b) Operatives	102,060	103,784	117,000	1.7
(c) Scientifically qualified	6,176	7,406	9,500	5.5
Capital:				
Total employed £M	230.6	406.8	600	12.7
Research and Development:				
(a) Annual cost £M	8.5	11.2	19–20	11.3
(b) Employees, total	10,100	10,914	13,000–14,000	4.2
(c) Employees, scientifically qualified	3,000	3,267	4,000–4,500	5.2
(d) Annual cost per scientifically qualified employee £	2,830	3,425	4,500	5.9
Exports:				
Value £M	88.25	151.70	200	10.8

average figure for all branches of the industry and of course some of these have advanced more rapidly and others more slowly than the average. The figures in Table 3 show that while in 1948 the total turnover in chemicals produced in the U.K. was made up of 45% due to inorganic chemicals, 26% by heavy organic chemicals and 29% by dyestuffs, pharmaceuticals and other small tonnage organics, these contributions had changed by 1956 to 41%, 38% and 21% respectively. Another way of looking at it is that, of the increase in turnover between 1948 and 1956 of just over £500,000,000, 38% was due to increased activity in inorganic chemicals, 45% to heavy organic chemicals and 17% to small tonnage organic products. The most spectacular increase was shown by basic heavy organic chemicals, the production of which increased nearly six times in the period under discussion.

The man in the street and the woman in the home have had no need of statistics to make them aware of this growing importance of heavy organic chemical products, because of the direct impact of synthetic plastics, rubber, textile fibres and detergents on everyday life. In the past decade, these have ceased to be "ersatz" materials good enough in an emergency to replace wood or metal and wool or soap but are products with distinctive properties which sell them in their own right.

The growth of the U.K. plastics industry has been quite spectacular. In 1956 the value of its production of resins, moulding powders, etc. reached £101.4 M. not far short of four times the corresponding figure for 1948 and there is still no sign of any slackening in this rate of progress. The most marked growth has been associated with thermoplastic products, particularly with polythene, polyvinyl chloride, polymethylmethacrylate and polystyrene. These are now such familiar and established products that it is extremely easy to forget that the first three were first produced in quantity as recently as World War II and that polystyrene was not produced at all in the U.K. until towards the end of 1950.

Polythene, originally discovered by I.C.I. in Britain in 1933 was first made in a large scale continuously operated plant in 1939 and for several years was absorbed almost entirely into wartime projects such as Radar. By 1948 U.K. production reached 2,000 tons a year, all from ethylene made by dehydration of alcohol and the present wide

pattern of peacetime uses in electric cables, food wrapping and domestic utensils began to emerge. It was not however until after 1951 when petroleum ethylene became available that this versatile plastic was given a free rein. In 1956 nearly 40,000 tons was produced, all of it by I.C.I. This output was increased considerably in 1957 when a second ethylene production unit came on line and further extensions now in hand will soon bring the capacity of this one source to some 90,000 tons a year.

Ability to make polythene in a range of qualities both by adjustment of the operating conditions of the original high pressure process and by adoption of the newer Ziegler or Phillips low pressure method, has contributed to continued extension and diversification of its uses and to the entry of several new manufacturers. For about a year the Shell Co. has operated a 1,000 tons a year pilot plant near Manchester producing Ziegler type product and it is now considering the erection of a larger unit. Early this year Union Carbide put on stream a high pressure polythene plant at Grangemouth which is also the location for a Phillips unit shortly to be completed by British Hydrocarbon Chemicals. Further, at Fawley near Southampton, Monsanto are erecting another plant to operate a high pressure process. All three of these plants will initially have a capacity of the order of 10-12,000 tons a year and there is every reason to believe that by 1960, the total U.K. capacity for polythene of all types will reach about 130,000 tons a year.

Turning now to polyvinyl chloride, the U.K. was definitely behind the United States and Germany in the development of this product as a plastic material and, at the end of World War II our production capacity was not much more than 5,000 tons a year. It very quickly established itself however in electric cables and in moulding powders and as a better product than nitrocellulose for many types of coated fabric. More recently it has found a rapidly increasing use in its unplasticised form for unsupported sheet used instead of metal sheet in a wide variety of light industries. An important new developments is the bonding of PVC to metals which makes possible the production of thin plastic coated metal sheet by rolling operations.

Polyvinyl chloride manufacture in the U.K. is mainly in the hands of Bakelite, British Geon and I.C.I. Production had risen to 63,000 tons a year by 1956 and is expected to be about 110,000 tons a year by 1960. All PVC made in Britain comes from acetylene derived from carbide and is therefore essentially based on coal.

Perspex or polymethylmethacrylate is another plastic whose manufacture was pioneered in the United Kingdom. It served many useful wartime purposes and its peak production rate in World War II was about 4,500 tons a year. One of its early peacetime uses was for dentures but its employment for high quality mouldings and for plain and corrugated transparent sheet soon became much more important. For many purposes it is still the best transparent plastic material and it is used extensively in street lighting fixtures. I.C.I. is the sole manufacturer in the U.K. and currently makes about 15,000 tons a year.

The United Kingdom relied on imports of styrene and polystyrene until 1953 when Forth Chemicals, a joint company of British Petroleum, Distillers and Monsanto commenced manufacture on a scale of about 10,000 tons a year at Grangemouth. The capacity of this plant has since been trebled and it has been reported that the Shell Company is also contemplating manufacture. U.K. production is expected to reach a total of 50,000 tons a year by 1960.

A number of other reasonably established plastic and resin products must be given a brief mention. Activity in phenol formaldehyde resins has been somewhat static but urea formaldehyde products have gone ahead mainly as adhesives and in ply chip board manufacture. The acetyl resins, particularly those based on pentaerythritol and epoxy resins have made great headway in paints and enamels and the polyesters have been important in connection with wood lacquers and in glass film laminated plastics. The latter has not yet achieved great prominence but they are being used in boat building and to a limited extent in the automobile industry; volume of production increased nearly six times in the past six years.

Mainly because of the lack, until recently, of adequate internal supplies of butadiene, manufacture of butadiene copolymers in the U.K. started relatively late. However, in 1957, four companies—Monsanto, I.C.I., British Geon and Dunlop made their first sales of these products from new production facilities, the principal outlets being to shoe soling compositions, emulsion paints, paper finishing and special oil resistant wetters.

TABLE 3

U.K. CHEMICALS PRODUCTION

Product Groups	1948 £M	1956 £M	Increase between 1948 and 1956 £M	% increase from 1948–1956
Basic Inorganic Chemicals	89.0	215.0	126.0	142
Fertilisers	31.2	77.7	46.5	150
Industrial Explosives	10.5	21.8	11.3	107
Miscellaneous Inorganics (approximately)	10.5	19.5	9.0	86
Total Inorganic Chemicals	141.2	334.0	192.8	137
Basic Heavy Organic Chemicals	19.0	112.0	93.0	485
Plastics	27.0	101.4	74.4	275
Man-made Fibres	37.4	97.0	59.6	160
Total Heavy Organic Chemical Production	83.4	310.4	227.0	270
Pharmaceutical and Veterinary Products	64.1	135.2	71.1	111
Dyestuffs	21.6	28.9	7.3	34
Miscellaneous Organics (approximately)	5.2	9.7	4.5	86
Total Pharmaceuticals, Dyes and Miscellaneous Organic Products	90.9	173.8	82.9	90
Total Organic Chemicals	174.3	484.2	309.9	178

An even later start is being made with general purpose synthetic rubbers but a plant to produce 50,000 tons a year will soon be brought on line at Fawley by a consortium of rubber manufacturers operating as the International Synthetic Rubber Co. Limited.

Yet another late start has been in the production of foamed plastic products based on polyesters or polyethers and the di-isocyanates which are in increasing demand for heat insulation and constructional purposes. A large plant to produce the necessary base chemicals was started up by the Dyestuffs Division of I.C.I. in 1957.

This then is the brief story of plastics in the U.K. in recent years and I think that it can fairly be claimed that this part of the chemical industry is in quite a healthy condition. It covers effectively pretty well the whole field of plastics—the only major omission I can think of is polyvinyl acetate—and it is substantially independent of imports. On the other hand it has for a number of years succeeded in exporting about 30% of its production to overseas markets. Manufacture of plastics in the U.K. is spread over a reasonable number of competitive firms, a fairly high proportion of which are partly or wholly foreign owned and have access to developments arising outside Britain. At the present time some 22% of the capital of the industry represents U.S. investment.

Closely related chemically to plastics and synthetic resins are the truly synthetic fibre products, Nylon, Terylene and the various acrylic materials.

The first of these to be made in the U.K. was of course Nylon under license from DuPont. British Nylon Spinners, a joint company of Courtaulds and I.C.I. commenced pilot scale manufacture in 1943, but it was not until 1950 that they completed the first full scale spinning plant with a capacity of 10,000,000 lbs. a year at Pontypool. Simultaneously I.C.I. started up a new plant at Billingham to produce not only the final polymer but also to synthesise, from benzene, the intermediates adipic acid and hexamethylene diamine.

Since 1950 there has been rapid expansion of both the spinning and chemical activities. Additions to the Pontypool plant brought yarn capacity up to 30,000,000 lbs. a year in 1954 and the new plant in Doncaster has increased this to 55,000,000 lbs. a year. As well as expanding its Billingham plant, I.C.I. has erected an additional large polymer producing unit at Wilton.

Terylene, the polyester fibre based on terephthalic acid and ethylene glycol, was missed by Carothers in the research he did on polyesters prior to his outstanding work on Nylon and was discovered by Whinfield of Calico Printers Association in 1941. Its subsequent development in the U.K. both on the spinning and chemical sides has been carried out by I.C.I. A pilot plant was operated at Hillhouse from 1951 and commercial production started in 1955 on completion of an 11,000,000 lbs. a year plant at Wilton. Expansion of the plant to 22,000,000 lbs. a year capacity was put in hand almost immediately and the extensions came on line in 1957. Further expansion to 30,000,000 lbs. a year will be achieved this year and new facilities are already sanctioned to bring capacity to 50,000,000 lbs. a year by 1960. Only a few weeks ago it was announced that the company expects to erect a Terylene spinning plant in Northern Ireland.

The value of Nylon and Terylene production in the U.K. in 1957 has not been published but by 1956, before the first major Terylene extension was operating, the figure was around £20,000,000. The comparable figure in 1948 was considerably less than £1,000,000.

Although Terylene was an entirely British invention made in 1941, its commercial exploitation in the U.K. began considerably later than large scale manufacture of the same product under the name of Dacron by DuPont in the United States. This fact has sometimes been cited as an example of the alleged slowness of British chemical and other industries in following up scientific discoveries by adequate technological development. In the case of Terylene at least the true reason is quite different. Whereas in the U.S.A. the basic raw materials for Terylene, ethylene glycol and paraxylene, were provided relatively easily by other branches of the American chemical industry, their production in the U.K. had to wait for the building up of the new petroleum chemical activities which we shall shortly be discussing. Supply of paraxylene was the main problem. The availability of mixed xylenes from coal carbonisation was quite inadequate and even when Shell introduced platforming into their refining operations there was not enough of this material to provide the requirements of paraxylene by the simple process of freezing out this isomer as practised in the United States. I.C.I. had to develop an elaborate process for increasing the yield of para from the available mixed xylenes which involved the isomerization of the ortho and meta components.

I mention this partly in defence of British chemical engineering which, at any rate in the large firms, I think is of a high standard, but mainly as an example of the way that introduction of a major new organic chemical end product makes far reaching calls on other branches of the chemical business.

Considerable quantities of the acrylic fibres have been imported into the U.K. in the last two or three years. Courtaulds have erected a plant at Grimsby with a capacity of 10,000,000 lbs. a year of Courtelle acrylic fibre and Chemstrand Limited, a subsidiary of the U.S. Chemstrand Corp., will have an acrilan plant operating in Northern Ireland early in 1959. This will also have a capacity of around 10,000,000 lbs. a year. Acrylonitrile for these new projects will be provided from facilities being erected by U.K. chemical firms.

The production of viscose fibres increased rapidly between 1948 and 1954 but since then has been relatively steady. The quality and particularly the strength of viscose yarns has greatly improved during the period under review and in the U.K. high tenacity viscose still holds the field as a tire cord material. In the acetate field cellulose triacetate fibres came into production in 1954 and are being sold as "Tricel". As a result of the recent merger of Courtaulds Limited and British Celanese over 80% of the U.K. viscose and acetate production is in the hands of this single group which is also the sole U.K. producer of cellulose triacetate.

Synthetic detergents now constitute a most important sub group of heavy organic chemicals but, as far as this paper is concerned, I can deal with them only briefly. Teopol made by sulphonation of high olefines from wax cracking is of special interest because it originated in the U.K. with a plant erected by Shell at Stanlow in 1942. On a volume basis, dodecyl benzene is now more important. Since 1955 it has been manufactured at Grangemouth by Grange Chemicals, a joint company of British Petroleum, Distillers and the American Oronite Company. It is reported that Shell will also manufacture shortly and by 1960 total U.K. production of this product is expected to reach over 40,000 tons a year. Non ionic detergents based on alkyl phenols and ethylene oxide are made by I.C.I.

So much then for the main organic end products which have a major impact on the public and on users outside the chemical industry and are therefore well known. I want now to say something about the much less publicised business of providing the basic organic chemical raw materials and intermediates for those projects, which, as I have already indicated when referring to Terylene, have been perhaps the biggest problem in the British chemical industry in recent years.

At the end of World War II, the United Kingdom was still practically entirely dependent for its basic organic chemicals on coal carbonisation as a source of aromatics, on carbide for acetylene, on coke for synthesis gas and on vegetable products, mainly molasses, as a means of entry into a very wide filed of aliphatic raw materials. Some of these classical routes were then and are still quite adequate. For example, we are extremely fortunate in the U.K. that coal carbonisation is practised on such a large scale for production of metallurgical coke and of gas for domestic use that it can still satisfy the chemical industry's demands for benzene, toluene, naphthalene, anthracene, cresols and, more indirectly for phenols, aniline and most other aromatic raw materials. In fact, in the case of benzene, potential availability is more than double present chemical requirements and the balance is blended into motor spirit. Xylene is the only basic aromatic product which is not available in adequate quantity in the U.K. on a by-product of coal carbonisation.

Acetylene requirements have also been met with relative ease by extension with considerable technical improvement of calcium carbide production. The same applies to provision of synthesis gas for ammonia, methanol, pentaerythritol, etc. by coke gasification although, in this case, increasing scarcity and cost of high quality coking coals is making it more and more desirable to adopt an oil route.

It is when we come to the aliphatic building bricks —ethylene for polythene, styrene and glycol—acetone for Perspex and Ketone, long chain olefines for detergents and butadiene for synthetic rubbers, that the old routes, chiefly that via alcohol from molasses, are quite unable to cope.

The solution, of course, has been found in the development of petroleum as a source of chemicals. In the U.K. this has been very largely carried out by the chemical industry itself and I think that it is very much to its credit, that starting from scratch after World War II, the petroleum chemical business of the United Kingdom is shown, by the latest world statistics, to be second only in importance to that of the United States.

Serious entry into petroleum chemical production began in 1949 with Shell commencing manufacture of a range of alcohol and ketone solvents from propylene and butylenes from refinery gases, later to be supplemented by deliberate cracking of gas oil. The next step was the almost simultaneous completion in 1951 of naphtha cracking installations by three firms, British Hydrocarbon Chemicals, a joint company of British Petroleum and Distillers, Imperial Chemical Industries and Petrochemicals. These units were sited at Grangemouth, Wilton in Yorkshire and Partington near Manchester. Between them they had a cracking capacity for more than 500,000 tons a year naptha and they made available approximately 100,000 tons a year of ethylene and another 100,000 tons a year of propylene and C_4 olefines and deolefines.

It is a matter of considerable interest that the United Kingdom was the first country to embark on a large scale on the deliberate cracking of liquid oil feedstocks to produce chemical raw materials as the main products with a minimum of fuel by-products. Particularly when these installations were first planned around 1946 the generally accepted view was that, given large oil refineries, it was preferable to take propylene and butylenes as by-products of normal refinery operations and to supplement by-product ethylene production by deliberate cracking of by-product ethane and propane. However, as the demand for propylene and C_4 olefines as well as for ethylene has increased, more and more companies including large oil concerns all over the world have resorted to the deliberate cracking of naphta which not only gives a gas product much richer in ethylene but also produces butadiene as a primary product instead of it having to be made by dehydrogenation of butane or butenes.

Associated with the first U.K. cracking plants were facilities for converting the primary olefine products into other basic organic chemicals. British Hydrocarbon Chemicals erected a plant for the direct hydration of ethylene to provide some 30,000 (now doubled to 60,000) tons a year of ethyl alcohol and Forth Chemicals (Distillers and Monsanto) also put up at Grangemouth facilities for 20,000 tons a year styrene manufacture. The ethylene from the I.C.I. Wilton plant was needed largely for polythene but additional facilities were installed for the manufacture of ethylene oxide and for glycol. Shell's ethylene and ethane provided the basis for manufacture of ethyl chloride for tetraethyl lead. At this stage the main provision for propylene usage was in plant for the manufacture of isopropanol, acetone and other organic solvents. It has been estimated that by 1952 £40,000,000 to £50,000,000 capital expenditure had been put into these petroleum chemical projects and that they were capable of producing per annum about 35,000 tons of ethyl alcohol; 10,000 to 20,000 tons of chlorinated solvents from ethylene; 30,000 to 40,000 tons of ethylene oxide and derivatives; 16,000 tons of styrene; 60,000 to 70,000 tons of isopropyl alcohol, acetone and derivatives; and 10,000 tons of secr. butanol and methyl ethyl ketone.

Since 1952, both British Hydrocarbon Chemicals and I.C.I. have brought additional cracking capacity on line and the latter has under construction a third unit which will be in operation by 1959. Shell is expanding the petrochemical plant at Partington which it purchased in 1955, and Esso has under erection a new plant for cracking some 250,000 tons a year of light distillate and this is expected to be on stream in 1958. Altogether ethylene production capacity by the end of 1958 is likely to reach 250,000 tons a year.

Several important new user plants for conversion of the basic olefines to materials which still come under the heading of basic organic chemicals have been installed since 1952 and others are in course of erection. The capacity of British Hydrocarbon Chemical's synthetic alcohol plant has been doubled and Forth Chemical's plant for styrene has been expanded to a capacity of 30,000 tons a year. Union Carbide is also building a 20,000 ton a year plant at Fawley for manufacture of ethylene oxide and related products from Esso ethylene. Shell already operates a 20,000 ton a year unit for propylene tetramer, the basis for alkyl aryl detergents, and British Hydrocarbons also have manufacturing capacity for some 11,000 tons a year of this product. I.C.I. has extensively developed the Oxo or carbonylation process and since 1951 has been applying it on a large scale to propylene and to a variety of petroleum derived C_6, C_7 and C_8 olefines to make normal and isobutyl alcohols and a range of higher primary alcohols used in the form of their dialkyl

phthalates as plasticisers. Another new use for propylene will be provided in 1959 on completion of a plant to make 7,000 to 10,000 tons a year of phen by the cumene process which has been installed by British Hydrocarbon Chemicals at Grangemouth. It is worthy of note that this phenol process was developed simultaneously by Distillers in this country and by Hercules in America.

A further major development has been the extraction of butadiene from cracker products which has been undertaken by I.C.I. and British Hydrocarbon Chemicals, both of which have large scale plants in operation. In the near future Esso will also be a major producer of butadiene both by direct cracking of light distillate and by conversion of butylene by the process developed by the Dow Chemical Company which is already in operation in Canada by the Polymer Corporation. The total U.K. availability of butadiene by the end of 1958 will probably exceed 50,000 tons a year.

These outstanding developments in the petroleum field involving capital expenditure to date which almost certainly exceeds £100,000,000 have, I think, effectively removed almost permanently any raw material bottleneck to the further progress of the organic chemical industry. The petroleum route to chemicals certainly as developed in the U.K. is unlikely to be prejudiced by changes in oil refinery practice because if necessary it could be based on crude petroleum instead of on particular oil fractions. The criticism is sometimes voiced that it is dangerous to make chemical industry so much dependent on a non-indigenous raw material. The practical answer to that, I feel, is that however optimistic one is about the future of organic chemicals, the oil needed for their production is only a few percent of the U.K.'s essential needs for oil for other purposes.

Time will permit only a passing word or two about the dyestuffs, pharmaceutical and agricultural chemical branches of the U.K. organic chemical industry. Expansion in these fields has not been so marked as with the larger tonnage organic products but nevertheless these branches remain highly active and they have continued to give birth to new and important products. Mention should be made in particular of the process dyes which by entering into chemical combination with cellulosic film can give the brilliant fast colors to cotton which were formerly possible only with wool. In the pharmaceutical field Mysoline, an anticolvulsant drug free from narcotic effects, has opened up an effective treatment for epileptics and Fluothane is a new non-inflammable anaesthetic with freedom from post-operative sickness and other undesirable effects. Gibberellic acid, an antibiotic type of product with quite fantastic effects on the growth of many plants, has also been developed in the U.K.

A characteristic feature of these fields of chemistry is that maintenance of a position in the business demands a continuous stream of novel products and this in turn calls for heavy research and development expenditure. This can only be justified by world wide application of any new discovery and this is one of the reasons for the high proportion of U.K. manufacturing concerns in this field which are partly or wholly financed from overseas.

I now come somewhat guiltily to the inorganic side of chemical industry which still accounts for 41% of the total U.K. turnover in chemicals and which has shown an average growth of about 12% per annum in the last decade.

Here again, however, much of this expansion can be attributed to the phenomenal developments in plastics, synthetic fibres and detergents. In the past five to six years, chlorine production has increased by 50%, largely to keep pace with increasing consumption in the manufacture of polyvinyl chloride, chlorinated waxes and chlorinated solvents and for indirect oxidation processes such as the production of ethylene oxide via chlorhydrin and of phenol via chlorobenzene. The need for nitric acid as an oxidising agent in production of adipic and terephthalic acids for Nylon and Terylene respectively has not only necessitated the extension of production facilities for nitric acid itself but also for ammonia. Similarly the growing requirements of acetylene for polyvinyl chloride tri and per chlorethylene and acrylonitrile have been responsible for the extension of both the Distillers' and I.C.I.'s calcium carbide plants and for the new carbide project in Northern Ireland which has been undertaken by a subsidiary of the British Oxygen Company.

In addition to supplying raw materials and reagents for the new organic developments, the inorganic side of the industry has also been called on to provide a number of auxiliary products. For example the growth of the plastics industry has led to a large demand for fillers. This has been met by the erection of a new carbon black plant by Philblack Limited in 1951 which now has a capacity of 50,000 tons a year and by the introduction of a range of silica calcium silicate, aluminium silicate and calcium carbonate filler products mainly by Joseph Crossfields & Sons and I.C.I. A second important example is the production of sodium tripolyphosphate, required as a component of synthetic detergent powders. By 1953 Britain was importing over £2,000,000 worth a year of this product but the country is now largely self-supporting as a result of manufacture by Albright & Wilson and its subsidiary Marchon Products.

The inorganic chemical industry has had its own raw material worries. In 1952 the serious world shortage of elemental sulphur caused U.K. sulphuric acid manufacturers to turn to anhydrite as raw material and in 1955 a consortium operating as U.S.A.C. brought into production a plant operating the cement sulphuric acid process with a capacity of 150,000 tons a year of 100% acid. Later in the same year Marchon Products erected a similar plant at Whitehaven with an acid capacity of 100,000 tons a year.

In an entirely different field there has been a growing concern about the use of coke as a raw material for synthesis gas, not so much on account of physical shortage as because of its increasing cost. This year Shell will bring into operation the first synthetic ammonia plant in the U.K. to operate on refinery gas, while I.C.I. at Billingham will bring on line a 60,000 ton a year ammonia unit based on the Texaco Process for production of synthesis gas from fuel oil. These two plants may well mark the beginning of a change from coal to petroleum as the raw material for ammonia.

Finally I must mention a few examples of new inorganic chemical products not connected with the major organic developments. Silicones, originally discovered by Professor Kipping of Nottingham University and now manufactured by two British firms, Midland Silicones, a subsidiary of Albright & Wilson, and I.C.I. They are finding a wide range of uses in textiles and in polishes and in water repellants for masonry. Related to silicones we have pure elemental silicon which is being made, although as yet on a small scale, for use in transistors.

A demand for Argon, a material not previously produced in Britain, for arc welding and for use in certain chemical processes has been satisfied by manufacture by British Oxygen Company and by I.C.I., the latter using a purge gas from synthetic ammonia plants as the source. One of the uses for Argon is in the production of titanium by sodium reduction of titanium tetrachloride, a process originated and operated on a commercial scale since 1955 by I.C.I. at Wilton.

There I am afraid I must bring to an end this very condensed story of the U.K. chemical industry. It has been, as I forecast, full of omissions but I hope it has been sufficient to show that the industry spreads itself effectively over the whole chemical field, that it is quite well integrated as regards provision of raw materials, intermediates and final use of products, that it is up to date in its processes and methods and that it is quite reasonably productive of new products and ideas.

Forecasts are always dangerous, but personally I feel confident that the industry will remain a rapidly expanding one for many years, particularly in the field of organic products which are continually finding new applications and for which the consumption per capita in the U.K. is still considerably less than that already achieved in the United States.

I have not had time to deal with recent progress except in the chemical manufacturing industry itself, but side by side with the progress I have described great strides have been made in improving and building up facilities for chemical plant design and construction and for the education and training of chemical engineers. All this should free the chemical industry in the future from some of the restrictions which it has had to face in its development so far.

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The Chemical Industry in France

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In a book by André Siegfried (which–incidentally–is largely devoted to Canada), . . . we are reminded once again, that our modern ideal of the infinite value of the *individual*, as he says, "may be traced directly back to its origin in the 18th Century". The author then goes on to say that "our industrial methods and procedures–even including the contributions made by the Americans–are actually products of this same 18th century, which witnessed the birth of the steam engine, and the division of labour operations, as well as the system of manufacture by chain production and the assembly line". And he concludes with these words, " . . . the inventive spirit, the refusal to submit to fatalism, and the spirit of individualism, with its concealed ferment of creative revolution . . . these are the principal elements that may be discerned at the generative depths of the European creative spirit".

I have repeated these phrases to you to-day, because they seem to apply so neatly and so well to the early advances and the first accomplishments of French chemistry. It was during the 18th Century that Lavoisier carried out his pioneering work and basic experiments, that Berthollet set up in Paris the first manufacturing of "Eau de Javel", that the first artificial soda plant was established and operated in accordance with the processing procedure invented by Nicolas Leblanc, in order to manufacture a substitute for the quantities of natural soda which were being held up beyond the frontiers by the Continental Blockade.

The 19th century was itself no less rich in outstanding discoveries. For example, it witnessed not only the first organic syntheses, which were affected by Berthelot, and the synthesis of fuschine, which was accomplished by Verguin; but it also heard Chardonnet's paper on the manufacture of artificial silk, which was presented to the Academy of Sciences in 1884, and witnessed the preparation of fluorine by Moissan, as well as Frédéric Kuhlmann's processes for producing sulphuric acid and nitric acid by catalytic oxidation.

A powerful impetus was thus provided by these precursors, both leaders and followers, whose pioneering labours have dominated chemical science ever since. In the subsequent history of French chemistry, however, this original impetus and vigorous forward movement has been seriously interrupted on two different occasions in recent years.

There is no other industry, I believe, that calls for a higher degree of steady continuity, in both its research and in its production phases, than the chemical industry; and this is because of the special requirements of its materials and its equipment, which are peculiarly liable to suffer damage and deterioration, and therefore demand constant up-keep and maintenance–and, also, because of the continual change and development in technical procedure and the continual discovery of new reactions.

In the light of these facts, you may easily imagine the crushing set-back which had already been suffered by our industry in 1918. Plants located in the invaded areas had been reduced to smoking ruins, and in the remaining parts of the country, chemical plants suffered severely from the scarcity of material resources.

In spite of all this, however, it was only a very short time after the end of World War I that new discoveries in the chemistry of coal were made, in a coal-mine which the returning miners found partly destroyed and partly flooded. The industry began immediately to put these new discoveries to good use, with the result that, during the interval between the two wars, the chemical exploitation of coal became one of the principal mainstays of the chemical industry.

The earlier disaster was re-enacted on a much larger scale in 1945. Many of our production plants with their equipment had been partially destroyed, others had been stripped of their vital components, and still others had deteriorated very badly indeed, owing to four years of neglect and lack of maintenance. Communications had been destroyed in part. There were shortages of coal, steel, cement, gasoline and pyrites. The whole economy was short of capital.

There were, in fact, shortages of practically everything, except the determination to win back an honourable position among the industries of the world. I should now like to try to demonstrate to you that, in spite of everything, we have finally succeeded in doing just exactly that.

As might be expected in the oldest branch of the chemical industry, developments, within the field of the inorganic chemicals have, in recent years, lagged behind those within the younger and therefore more dynamic sector of the organic chemicals, which enjoy much brighter prospects. This fact is illustrated strikingly by a comparison of the indices of industrial activity in 1957, on the basis of 100 for 1952. This shows a figure of 189 for the French chemical industry as a whole, with 152 for inorganic chemicals, taken by themselves, and 294 for organic chemicals.

As I propose to make only a very rapid survey, I shall mention merely the main products. The first which comes to mind is sulphuric acid.

This is a typical example of a product whose consumption has barely fluctuated within France over the past 30 years. With a total production of over 2 million

tons in terms of monohydrate, the 1957 output was 1,620,000 tons, and this is the highest figure of any one year, in France. Actually, it is only 5.5% higher than the previous record, which was set nearly 30 years ago, in 1929.

Such a very limited expansion is accounted for, by a steep decline, in recent decades, in the consumption of fertilisers using sulphuric acid; and this has been only partially offset by an increase in the demand for this product by artificial textiles, chemicals, metallurgy and oil refining. In 1929, about 80% of the acid produced was used, either directly or indirectly, for agricultural purposes. In 1957, the corresponding figure was only 50%.

This proportion will no doubt decline still further in the future, owing to the new needs of industry, as in titanium oxide production or in the treatment of uranium ores, which are rapidly expanding in France at the present time.

Do not infer, from what I have just said, that the demand for fertilisers in agriculture has declined since 1929. I shall show, in a moment, that this is not the case; in fact, the precise opposite is true. As regards phosphoric acid (P_2O_5), however, (although consumption has in fact risen by 70% between 1929 and the present time), the demand for sulphuric acid in the form of ordinary superphosphate, a heavy consumer of this product, has fallen off by nearly one half, with the gap being filled by slag and ground phosphates, which do not need any acid, as well as by more concentrated and complete fertilisers of the "ternary" type, which require no sulphuric acid, or less of it than ordinary superphosphates.

After this brief digression, let us now examine the processes used for manufacturing sulphuric acid. We see that, in France as in other countries, contact plants are increasingly being substituted for lead chambers. In 1937 over half the total production came from contact plants, whereas in 1938 the proportion was only 21%. By the same token, small production units are gradually being ousted by high capacity plants using heat recovery, and with a high sulphur yield.

The constant preoccupation with high yields, common to all of the manufacturing industries in France, is, in the case of sulphuric acid, the consequence of the country's shortage of ore supplies, up until quite recent times. To meet an annual consumption of sulphur, or sulphur equivalent, of about 700,000 tons, metropolitan supplies of pyrites hardly represented the equivalent of 130,000 tons.

The opening up of the LACQ gas deposit, one year ago, will totally transform the supply outlook for our works, many of which are still equipped for roasting pyrites.

The LACQ gas has a hydrogen sulphide content of 15%, and will release 60,000 tons of sulphur per year, for an output of 1 million cubic meters of crude gas per day

Already LACQ is turning out 5,000 tons of sulphur a month. This figure will be increased fivefold by the end of this year, tenfold by July 1959, and twentyfold at the end of 1960, when it will be in the neighbourhood of between 1,200,000 and 1,300,000 tons a year, with the possibility of twice that amount.

Thus France may become the world's second sulphur producer, after the United States and equal to Mexico. This would bring about a very substantial drop in imports of sulphurous materials; and beginning in 1961, it is planned to export an annual quantity of something like 700,000 tons.

Such a complete revolution in our supply position is doubtless liable to cause further changes in the manufacture of sulphur derivatives and fertilisers. This brings me to the fertiliser industry, with an annual turnover which, at the present time, still accounts for more than one quarter of that of the chemical industry proper; and 60% of the total within inorganic chemical field.

The Fertilizer Industry

The fertiliser industry has always played a prominent part in France, because, apart from the sulphur we have just been talking about, there has never been any lack of the other essential raw materials needed for manufacturing fertilisers.

The rich potash deposits of Alsace alone account for 15% of the world's known reserves of this mineral. Under dynamic management, and thanks to substantial investments during the past few years, output has tripled since 1938, and doubled over the last ten years. The 1957 production figure of 8,830,000 tons of crude salt was a record; the 1,600,000 tons of potassium oxide which this represents, more than suffice to cover the needs of the home market for fertilisers; and therefore over one half of this amount is exported.

North African phosphate production has again soared since the end of World War II, and has provided ample supplies for the home market. The Moroccan mines alone have doubled their output in 10 years to roughly 6 million tons of ore in 1957, allowing a substantial increase in high grade phosphatic fertilisers; while the production of ordinary superphosphate decreased by one half since 1929; but it will continue for a long time to come, thanks to plant concentration and modernisation of equipment. The former system of intermittent dens has been replaced by continuously operating, automatically fed units.

Lastly, the third nutrient element, nitrogen, has so far followed much the same rate of progress as in the United States and the OEEC countries, where from 1949-50 to 1956-57 production has rather more than doubled. During the same period in France it rose from 234,000 tons to nearly 500,000. By 1959, productive capacity should reach 700,000 tons.

All these figures will show you that the French nitrogen industry has succeeded in adapting itself to an ever-growing demand.

This has been made possible

—by the building of new plants,

—by the enlargement of the capacity of existing plants, and the scrapping of small units,

—by the active research for new basic raw materials for the preparation of hydrogen. In 1938-39, 61% of the synthetic ammonia produced came from coke-oven gas, 33% from coke, and the small remaining percentage from electrolysis. In other words, nearly the whole nitrogen output was dependent on the coking plants, either directly through gas, or through coke.

Since that time, a very marked trend towards the elimination of the use of coke has set in. The proportion falls to 6% in 1958; and in two years' time it is likely to be nil. The proportion accounted for by coke-oven gas is slowly but steadily declining, though still rising in absolute figures. At the present time it is not more than 52%. The use of oil refinery gas is expanding; and the cracking of crude oil started in 1953. Above all, however, the use of natural gas in South West France is steadily increasing, and now accounts for 26% of the total.

To sum up then, the trend in France has been the opposite of that in the United States. For some years now, only the latter country has been relying on the hydrogen

from coke-oven gas with which we began. The fact is, that Americans have long been aware of their wealth of natural gas deposits, whereas our own deposits have only just recently been brought to our notice.

So far, I have been speaking only of the basic fertiliser elements, nitrogen, phosphoric acid, and potash.

For obvious reasons, the use of fertilisers in more or less homogeneous mixtures had been developed during the inter-war period, though not on a large scale. In 1935, mixed fertiliser supplies did not reach a total of 50,000 tons of nutrient elements.

Nevertheless, the use of chemical combinations of several elements offered advantages from three different standpoints:

—the homogeneity of the products,

—their higher analysis,

—and their greater ease in handling.

Two classes of so-called compound or "complex" fertilisers have been developed; those based on the nitric or sulphonitric acidulation of rock phosphates; and those with a phosphoric acid base and involving no nitric acid reaction, the principal of these being ammonium phosphate, possibly in association with potassium.

Production began in France in 1939; and its development and exploitation have spread rapidly since the war. The quantity of compound fertilisers manufactured in 1956-57 exceeded 1 million tons, and represented 36% of the total output of fertilisers containing more than one kind of plant food, as against only 400,000 tons or 25% in 1951; and the total nutrient content in the mixed and compound fertilisers now represents nearly 50% of the total fertilising elements consumption.

Before going on to organic chemicals, I should like to say a little more about chlorine, which is one of the few mineral products with an output which already in 1946, that is, immediately after the liberation, had reached, and even exceeded, the 1930 level. Since then, production has risen tremendously, and was in 1957 four times higher than it was in 1938.

The great expansion of chlorine production bears witness to the intimate relationship between the mineral and the inorganic chemicals. By its cheapness, and the reactions of which it is capable, this metalloid opens up the path for the development of a set of products that have assumed and will continue to assume a very considerable importance.

Organic Chemical Industry

This brings us to the achievement of the organic chemical industry. Its development over the past twenty years has been on such a scale, as to warrant special attention. The wealth of new discoveries and industrial achievements it has made possible is to-day most impressive.

Foremost among these, ranks one of the oldest: the synthetic dyestuffs industry. Despite its venerable age, it is still progressing at a lively pace, and is ever alert to make new conquests.

A hundred years ago—and just two years after the discovery of Mauveine by the Englishman, Perkin—the chemist, Emmanuel Verguin of Lyon perfected the process for manufacturing Fuschine. The new dye—the second in the series of synthetic dyestuffs—produced the most handsome of purplish red shades on silk.

These early successes gave research a new encouragement, and led to the establishment by Poirrier, in Saint Denis near Paris, of the first French synthetic dyeworks, and the cradle of the French dyestuffs industry. It was here that Paris violet, the Indulines and the Nigrosines were perfected.

Yet by 1914, the total output of synthetic dyes, in France, had only reached the modest figure of 1,000 tons a year.

The 1914-1918 War naturally gave a new impetus to the industry, which continued to expand after hostilities came to a close. New works were built at Villers Saint Paul near Creil, Oissel near Rouen, and Saint Clair du Rhône near Lyons. By 1939, the annual output exceeded 10,000 tons, more than a third of which went for export.

The sombre events of 1940-45 necessarily forced the French dyestuffs industry to slow down. The special administrative regime that was imposed upon it, for the next six years, allowed reduced activity only. It was not until 1951, after a hibernation of something like 11 years, that it recovered its normal possibilities of action. Vigorous measures were taken to modernise plants, to perfect and put into production the new dyes demanded by an increasingly exigent textiles industry, and to meet a competition that was becoming keener than ever before.

The dyestuffs industry is, in fact, one in which quality is all-important, and only first-class goods are competitive. This is what accounts for the tireless research that led to the production of vat dyes, dispersed dyes for artificial fibres, dyes for plastics, and many others too numerous to mention.

French production is concentrated in five large works; and it exceeds 15,000 tons in 1957.

Such is the progress made by this industry, which in its early days ruined the manufacture of the two main natural dyes, indigo and madder.

Pharmaceutical Industry

The reactions made use of in pharmaceutical chemistry are so closely bound up with those applied in the preparation of organic dyes that it would be as well to insert, at this point, a very short account of recent French achievements in the field of chemo-therapy.

Since World War II, a very great effort has been made in therapeutic chemistry in France, so much so that all I can do is to indicate the broad lines that research has followed.

Important work has been done on the antibiotics, both in the selection of the stocks that provide products capable of victoriously combatting germs that have now become adapted to standard antibiotics (more especially in the treatment of tuberculosis), and in the synthetic preparation of compounds of known antibiotics, whose scope and operational life have thereby been considerably extended.

In pure chemistry, the synthesis of a large number of amino-derivatives of phenothiazine has thrown new light on their manifold therapeutic uses, and enabled the most effective products to be selected. One of these, Chlorpromazine, has an amazing effect on the central nervous system, and was one of the first of the "tranquillisers" now so widely used throughout the world.

The study of quaternary ammonium salts has been no less fruitful, and many of these salts have been marketed for various purposes.

At the same time, a great deal of work has been done on producing new tuberculostatic substances derived from isoniazide or the sulphones, or making possible the synthesis of new medicines based on the action of vitamins or hormones. Among the latter we may

mention the cortisone derivatives, and those which slow down or moderate hypophysical function.

Unfortunately, this incomplete and not very exciting enumeration will have given you but a very inadequate idea of what has been done, in France, in the field of chemo-therapy, this science that is forever making new strides in the treatment and relief of the ills that beset humanity and at the same speed with which, in other spheres, man creates for himself new causes for distress.

At the beginning of this section were mentioned some of the extraordinary developments in organic chemistry. Between the two Wars these have wholly centred round the chemistry of coal.

There can be no doubt that the utilisation of catalytic reactions and the industrial applications of the main synthetic processes, have set organic chemistry on a new and particularly rewarding course. The manufacture of methyl alcohol from a mixture of carbon oxide and hydrogen followed closely after the building of the first synthetic ammonia plants.

The manufacture–by the fractional liquefaction of coke-oven gas–of the hydrogen required for ammonia synthesis, first made possible the incidental extraction of the small quantities of ethylene contained in the gas.

The industrial production of synthetic methanol provided a cheap way of manufacturing formaldehyde, and thereby opened the way to the phenomenal development of the first phenol/formal and urea/formol synthetic resins.

From 1925 on, factories sprang up on the coalfields, especially that of the Nord–Pas de Calais district, the only large producer of coking coal at the time. Mininig companies and chemical firms formed alliances to exploit both the gas from the coking plants and the electricity supplied by thermal power stations burning low-grade fuel.

In 1938 we produced:

8,000 tons of methanol
1,500 tons of formol
6,600 tons of phenol
2,200 tons of acetone.

It was then possible, by means of ethylene, extracted from coke-oven gas, in the form of mixtures containing 30% olefins, to produce, by an original process, 650 tons of ethylene oxide, yielding 725 tons of glycol.

Very soon after the end of hostilities, these first productions of organic chemicals were increased considerably, keeping pace with demands of the market. The coking of Lorraine coal, finally perfected after long research, led to rapid increase in France's coke production, which rose from slightly more than 7.5 million tons in 1938 to 12.5 million tons in 1957. Progress in coal chemistry continued in Northern France, where the ethylene from several coking plants is collected and brought to the heart of the coalfield for eventual use in oxide synthesis, to manufacture polyethylene and monomeric styrene. Carbochemistry also emerges and develops very swiftly on the Lorraine coalfields, for the production of dichlorethane, monomeric styrene and, using methane, acetylene and its acrylic derivatives.

By 1957 production had risen (as compared with 1938): fourfold in the case of methanol; tenfold in the case of formol, while the output of phthalic anhydride was increased twentyfold. We also produced: five times as much phenol, eleven times as much acetone, and seventeen times as much ethylene oxide.

Petrochemicals

For some of these products, however, petroleum has made a timely contribution to the supply of raw materials.

It might have been supposed that the already considerable scale on which the chemistry of coal has developed would have brought about a saturation of the market. In fact the striking success of the principal new products very soon demonstrated the contrary. The raw materials derived from coal distillation were insufficient to meet the demand. Some new and abundant source had to be found; and this was the origin of the French petrochemicals industry, the impressive growth of which has been a feature of the last five years.

For the time being, petrochemistry chiefly means the chemistry of ethylene and propylene, shortly to be supplemented by isobutylene feeding a butyl synthetic rubber works, with an annual capacity of 18,000 tons now under construction in the Basse Seine region, and butadiene for a GRS rubber works at present in the planning stage. In addition there are the higher olefines used in Oxo synthesis.

Petrochemicals are manufactured in the vicinity of the refineries whose by-products provide the raw materials, in many cases under the supervision of joint subsidiaries of the oil companies and the big chemical combines.

The oil refining industry first came into being under a law of 1928, and its development in France was swift. Ten years after the law was passed, the industry's refining capacity had already reached 8 million tons. Since 1946 the refineries have been rebuilt and enlarged, and new reforming and cracking units have been added. Their capacity has now risen to 31 million tons; and in two years' time should reach 36 million tons.

There are some ten petrochemical firms which have already for some years been engaged in the processing of hydrocarbons extracted from refinery gases or petroleum fractions to obtain: phenol and acetone, isopropanol and its derivatives, tetrapropylene and dodecylbenzene, alkylsulphates, ethylene oxide and its derivatives, propylene oxide and its derivatives, heavy or light oxo alcohols. Quite recently, carbon black and perchlorethylene plants have been put into operation.

Additional works are to be established in the Seine Valley area for ethylene oxide; in Southern France for propylene oxide, and for dodecylbenzene and perchlorethylene.

Very substantial capital has been invested, in Upper Normandy and Southern France, in four high and low pressure polyethylene plants. These are due to come into production over the next 12 months.

So oil has come to the assistance of coal, but it will not have escaped your notice that, unlike the latter, it is an imported product. Yet the future seems highly promising in this respect; and it is quite possible that we may one day obtain a large part of our supplies of crude oil from native sources. There is now a reasonable prospect that our petroleum imports will dwindle from year to year.

These are the grounds for such a hope:

The Parentis oilfield was discovered in the Landes region in 1954. Production began in 1955, and by 1957 output had already reached nearly 1.5 million tons, or 5% of France's total consumption.

A fact of capital importance to our country has been the discovery of oil at many points in the Sahara desert region, signifying in all likelihood the presence of a huge oilfield.

More especially, the Hassi-Messaoud deposit becomes more and more promising. During the past few weeks, the

first tankers carrying crude oil from the Sahara have been unloading at the French refineries. In the experts' view, this historical event marks the accession to the French economy of a source of supply that might well make it independent of imports.

The last twenty years have also been marked by the discovery of natural gas deposits in Southern France.

The little field of Saint-Marcet has been utilised since 1939 for domestic supply, producing about 300 million cubic meters per year; and ever since the end of the War, it has provided three ammonia works with part of their material supplies.

Subsequent explorations revealed the Lacq deposit in 1951.

This is a deposit of gas rich in hydrogen sulphide at a depth of 11,000 feet. The pressure is as high as 9,600 lbs./sq. in. and temperature at well foot is 285° Fahrenheit.

Such extreme conditions of pressure and temperature involved very ticklish operational problems, notably as regards the resistance of the tubings to corrosion. Indeed, at first the tubings failed to stand up to conditions. Yet special steels were devised by a French metallurgical firm and very soon yielded satisfactory results.

Daily output at present is over 1,000,000 cubic meters of crude gas. As I have said, this figure will have been multiplied twentyfold by the end of 1960, and there is every expectation that even this will be greatly exceeded thereafter.

This level of production represents, independently of the sulphur, and of the methane and ethane, an annual supply of: 140,000 tons of propane and butane; 240,000 tons of gasoline rich in aromatic products.

A gas transmission network is now under construction. In particular, it will supply gas for the chemical industry in the Nantes, Lyons and Paris regions.

Large-scale projects are in hand. The production of acetylene, ethylene, carbon-oxide and hydrogen opens up new prospects for the series of reactions widely used in America, resulting in methanol and plastics for instance.

Immediately after the War, we lagged far behind in the plastic field. Our production, which was at 35,000 tons in 1952, has risen to 150,000 tons in 1957. By 1960 it should satisfy all of our domestic needs and requirements.

As for synthetic fibres, we are now producing not only Nylon, and the polyvinylic fibres, but also Tergal, which corresponds to Dacron and Terylene, Crylor, which is comparable to Orlon, as well as Rilsan, which is a French fibre composed of a super-polyamide for which castor oil is used as a raw material.

These new synthetic fibres have now taken their places alongside our traditional production of artificial textiles, which is in the neighbourhood of 150,000 tons per year.

In 1961, our production quantities of synthetic fibres will be: 18,000 tons of Nylon; 9,000 tons of Tergal; 3,000 tons of Crylor; 13,000 tons of Rhovyl; 6,500 tons of Rilsan.

The exploitation of the natural gas deposit at Lacq should enable low cost electrical *energy* to be produced in the South West region, and this will constitute a substantial addition to our total production of energy.

Like all other countries, France is facing an ever-increasing demand for energy of all kinds. According to official statistics, these energy requirements will be doubled within the next fifteen years.

Our coal production, with its 59 million tons for 1957, is fast approaching the effective limit of 65,000,000 tons per annum. Fortunately for us, there are still potentialities for developing our hydro-electric power installations.

So there is no immediate threat of shortages in the French energy situation, at the present time.

It follows from this, that we have adopted a policy of prudence and caution, so far as atomic programs are concerned; and our current activity in the field of reactors is mainly confined to the production of prototypes.

The E. d. F. is planning, every eighteen months, to bring a new pile into operation, which will represent an improvement over the previous one, the aim of this policy being to throw more light on the economic and technical phases of the whole problem, and their bearing on the future.

E. d. F.'s first industrial power station, which is now under construction in the Chinon district, will have a thermal capacity of 300 MW and an electrical output of 60 MW. It is anticipated that by 1965 we shall have a total power potential of 850 MW from nuclear sources alone.

In the meantime, and for guidance in these industrial developments, France has established several large research centres, the most notable among them being at Saclay and Marcoule. Each of these centres has long since been equipped with numerous experimental piles.

In the over-all effort bearing on pilot project and industrial prototypes, France is fortunately able to rely on abundant uranium reserves which certainly exceed 100,000 tons of metal, including more than 10,000 tons which have already been confirmed.

This will make it, so far as is known, within several years, the Western World's 4th largest uranium producer, after Canada, the United States and the Union of South Africa.

Two plants for the chemical treatment of ores are now in operation, producing uranium-bearing concentrates, with a 60% uranium content. These are the Gueugnon plant in Central France which processes 50,000 tons of high grade ore per year, with an uranium content of about 1% and the Ecarpiere plant in Western France, with a yearly amount of 150,000 tons of low grade ore, with a uranium content of about one per thousand, which will rise to 300,000 tons per year by August 1958.

A third plant is under construction at Bessines in Central France. It will be put into operation in July 1958, with an initial processing capacity of 200,000 tons per year, and it will be handling 600,000 tons by the end of 1959.

A fourth plant is planned in South-Eastern France near Vichy to handle 200,000 tons, in its first phase, beginning in 1960.

Concurrently, we have a plant in the Paris region, which has been in operation for several years now, processing concentrates to obtain uranium metal; and another plant is currently being built in Southern France.

The French uranium production program for the next few years is as follows: 500 tons in 1958; and 1,000 tons in 1961; the target, for 1975, is 3,000 tons.

Private enterprise in the chemical sector has played the leading part in setting up these uranium plants.

It also figures prominently in other branches of the nuclear energy field in France, and to the extent that its contribution is needed.

The three classic moderators for slowing down neutrons, graphite, berylium oxide and heavy water, are either produced, or are about to be produced in France.

Quality graphite, of nuclear purity, is manufactured on a large scale, and more than satisfies French require-

ments. The process for manufacturing berylium oxide has also been perfected; and large quantities have already been produced, though this substance is not yet widely used in French atomic piles.

A first pilot plant for the production of heavy water is to be put into operation shortly, and will function by extracting deuterium from liquid hydrogen. Trials are also being conducted, using gas from Lacq, with the isotope exchange process.

The French chemical industry has also devoted particular attention to developing structural metals, and a great deal of research on the subject has been carried out.

Considerable quantities of magnesium and aluminium are produced at excellent standards of quality. Studies have been made of berylium and zirconium. Ductile niobium, vanadium, molybdenum and chromium will soon be on the market.

Numerous auxiliary materials for the nuclear industry are prepared with highly satisfactory results: for instance, nuclear calcium for use in uranium metallurgy, or control and safety materials such as cadmium, or the liquid metals used in heat transfer.

Finally, in the treatment of irradiated fuels, France's policy was originally directed towards plutonium production, and a plant for processing enriched uranium was built at the atomic centre of Marcoule. Production is to begin there shortly.

Recently, however, it has been decided to conduct a parallel study of uranium 235, and plans for a uranium hexafluoride gaseous diffusion plant are already well advanced.

Incidentally, there is some prospect that this plant, costing between 50 and 60 billion francs, may be established on a broader basis than that of a purely national undertaking.

All of this makes France one of the most advanced countries of Western Europe as regards atomic projects and achievements.

This lengthy statement, however concentrated it may still be, does at least, I feel, give some faint idea of the specific progress made by the French chemical industry. In 1961, just three years from now, the total turn over figure for the French chemical industry, strictly speaking, will be in the neighbourhood of 800 billion francs and the chemical industry will play an essential part in restoring equilibrium to our import-export balance.

When we consider all of the new products the chemical industry has discovered and manufactured throughout the entire world, within only a century, we are truly amazed by the potentialities of the scientific manipulation of matter. The ceaselessly renewed achievements of this industry would seem to be pushing back its own boundaries almost indefinitely.

But such a rich history of achievements–some of which most impress us, because of their possible effects upon the future of the human race–do they not also impose obligations on all of us as well? Some of these obligations are best fulfilled by Governments. Others, however,–and not the least in importance–must be met by ourselves. These problems can only be solved by a sort of "calculated" wisdom; and by our determination to avoid scattered efforts, which are barren and costly,–and all the more costly, since we are faced with new problems at every moment.

A great experiment is now being attempted in this general direction,–and in our old Europe, recently weakened by two terribly destructive wars. This great experiment is the creation of the European Common Market and it is now coming progressively into operation. The paramount condition for its success is the need–on all sides–to abandon the spirit of domination, which springs from an immoderate desire for power and riches. Men must be made to realize that it is loyalty and justice which are the essential conditions for success, in the harmonious and wise carrying out of this great economic project and program.

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The Present Situation and Prospects of the Italian Chemical Industry — High Polymer Developments

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THE present situation and prospects of the Italian chemical industry is the subject I shall develop especially from the point of view of its historical, economical and evolutionary basis. I shall avoid all the statistical data of the various chemical productions, since they are reported in many publications.

In this short exposé I shall try to give an idea of how the Italian chemical industry was started, which were its developments in the last decades, what is presently the phase in evolution and especially, the trends of its future developments.

I hope that this outline will be interesting because it should demonstrate how spirit of initiative, hard work and confidence were able to overcome initial conditions that were exceptionally difficult.

The Present Situation and its Origin

Italy was a country that had neither coal available in its territory (excluding very low grade lignites with high cost of production) nor petroleum or metallic ores in any important quantity, with the exception of bauxites and iron pyrites.

It is well known that the primary factors in promotion of the chemical industry are the availability of raw materials and the general technological level. In Italy, the raw materials were very few. We can say that the Italian chemical industry started using air, water, salt and pyrites as raw materials; plants were located initially where power was locally available or where it was possible to use seasonal peaks of hydroelectric power.

This availability of electric energy not only made possible the beginning of certain electrolytical productions, like chlorine, soda, aluminum, but also synthetic ammonia was produced in 1924 from electrolytic hydrogen and methanol in 1928, from synthesis gas. The latter was produced in the first continuous low temperature coal gasification plants in the world using oxygen obtained as a by-product of electrolytic hydrogen production or of nitrogen production by air fractionation. The local availabilities of power became absorbed in more economically rewarding uses as the civil consumption of the same was growing in a country that was in a phase of development. Therefore they were less and less available to the chemical industry.

In a country thickly populated, having a limited tillable surface which was, however, extended to the most difficult and least fertile mountainous zones, it was natural to make the first move in the field of phosphatic fertilizers (needed in soils depleted by thousands of years of cultivation) and of nitrogen fertilizers. The latter field promoted the growth in Italy of the great chemical industry in the decade from 1925 to 1935.

From this first platform, the Italian chemical industry developed toward more complex productions like dyestuffs and pharmaceuticals in the period between the two world wars. In the same period there was also another important development favored by the already existing textile industry based on the use of natural fibers. Rayon was manufactured on a large scale so that Italy became one of the leading exporters of this cellulosic fiber.

In this period, Italy had also made great strides in the production of ammonia, calcium carbide, inorganic and organic acids and calcium cyanamid.

Although the Italian chemical industry grew later than the chemical industries of some other European countries, it developed some original concepts and techniques which in some instances contributed to the further development of the chemical industry in the world. Such contribution is considerably more than it would be predicted with the sole consideration of the limited Italian productions.

As an example we quote the high pressure synthesis processes (ammonia, methanol) developed in Italy and other manufacturing units connected with the same, which caused the construction of several plants outside Italy in Europe, America and Asia.

In the years immediately preceding World War II, the Italian chemical industry had attacked new advanced problems. In those years, hydrocarbon hydrogenation plants were built in Bari and Leghorn using some very heavy Albanian crude oils. Such industry could not yet be defined petrochemical since its main purpose was production of fuels, but already there was a trend to utilize certain byproducts to produce chemicals. Furthermore this was an indication that the Italian industry was aiming at special productions in large tonnages.

In the field of synthetic rubber in Ferrara, a plant was built in 1938 to produce butadiene from alcohol and Buna S. In this plant was the first unit in the world that allowed the separation of substances like butadiene and butylene having the same boiling point by extractive distillation. The construction of a plant to manufacture Buna S starting from calcium carbide was started in Terni, but the war prevented the start-up of operation. These plants were an indication of the level reached by the Italian chemical industry before the beginning of World War II.

This war brought severe destruction and damages that halted the development of the Italian chemical industry.

During the first years after the war all activity was directed toward the rebuilding of the productive structure of the whole country. The chemical production dropped in 1945-46 to figures quite below those of 1938.

In the last 10 years the Italian people have shown great energy and capacity for work and have rebuilt their country and their industry, going much further than they were before the war, as indicated by the monetary values shown in Table 1.

In the meantime, in Italy, probably preceding other countries of continental Europe, a deep modification of the old conceptions concerning the raw materials for the chemical industry, had taken place.

Before the war, most of the European chemical industry was based on coal; petroleum was not considered a suitable raw material for chemicals.

However, two new and important factors were added to the picture. The first factor was the availability of new raw materials, the second was olefin chemistry.

During the years after 1947, gas fields were discovered and exploited in Northern Italy. Table 2 shows the production figures from 1948 to 1957.

In addition, the increase in the oil production of the Middle East during the last years, the use of more and more efficient and economical transportation means and, last but not least, the geographical position of Italy has allowed the development of a petroleum industry, which has now an approximate capacity of 30 million tons per year of crude. This has disclosed new possibilities for the chemical industry.

The technique of obtaining chemical products from gaseous or liquid hydrocarbons was mostly developed in America during the war. It was almost unknown in Europe where, on the contrary, years of work were spent to obtain the opposite goal, namely synthetic gasoline instead of using the petroleum hydrocarbons as a raw material for chemical synthesis. The latter conception coupled with rationalization of chemical engineering is rightly considered a major contribution given by America to the development of the chemical industry.

During the years after the war, the conditions for the organization of chemical productions from hydrocarbons developed in Italy. Also, in this instance the Italians showed a considerable energy and initative and this time, too, new contributions to chemical progress were made.

This development extended in two main directions: the chemical derivatives of natural gas, which in Italy is practically pure sulphur-free methane, and the derivatives of olefines obtained from petroleum.

The first development is, from the point of view of quantities, more important; first ammonia was produced followed by methanol, acetylene, hydrocyanic acid and some chlorinated solvents. By 1949 the problem of the most complete possible chemical utilization of methane was studied. The products obtainable from this source and the corresponding processes were reviewed. Not all processes were available and some of the available ones were not suitable for the Italian conditions. It was therefore necessary to create suitable processes.

Pilot plants were erected, and at the end of 1951 the projects of two great factories were ready; their erection was carried out with great speed and energy and production began in 1953. Ever since, the ammonia production in Italy has been increasing: as shown by Table 3.

Other plants, for an additional production of 180,000 metric tons per year are now in an advanced stage of construction. At the same time, the whole methanol production, which was based on coke gasification, was shifted to methane as a raw material: Table 4 shows the increase of methanol production from 1952 to 1957.

The production of hydrocyanic acid, acetylene, chlorinated derivatives and other products was started. Another important production going to be actuated in Italy is a plant on advanced phase of construction, located in the vicinity of a natural gas deposit and having a capacity of 35,000 metric tons per year of synthetic rubber of the butadiene styrene type. The scheme, developed by a government industrial group, was initially based on butadiene derived from acetylene obtained from natural gas by partial combustion.

The residual gas from acetylene production will be converted into ammonia. This scheme was later modified to use acetylene for production of vinyl compounds and, starting from petroleum refinery gases, to produce butadiene. It was a courageous decision to decide to build a GRS plant having a capacity higher than Italian consumption, especially at a time when some revolutionary changes may be in the offing in the field of synthetic rubbers.

Acetylene from natural gas is converted in Italy into polyvinylchloride and into acetaldehyde. These productions will certainly increase in the future.

Today, approximately 12% of the Italian production of natural gas is utilized for chemical purposes. This is the highest percentage of any other country in the world. In the United States, which was able to utilize natural gas for chemical purposes almost 25 years ago, it is only 3% and this in a country where natural gas is not the only national fuel (which is practically the case in Italy), but

TABLE 1

ITALIAN CHEMICAL PRODUCTION

Year	Value in billions of Lira (present value)
1938	414
1948	414
1958	1,160

TABLE 2

ITALIAN PRODUCTION OF NATURAL GAS

Year	Millions of Normal cubic meters	Millions of Standard cubic feet
1948	113	4,210
1949	240	8,950
1950	490	18,300
1951	930	34,700
1952	1,380	51,500
1953	2,200	82,000
1954	2,870	107,000
1955	3,490	130,000
1956	4,300	160,000
1957	4,820	180,000

which is the first producer of crude oil and which has three quarters of the world's coal reserves.

In short, the Italian chemical industry has made a really appreciable effort towards the utmost chemical utilization of natural gas and this was one of its new development courses after the war.

The other course was, as already said, that of the high polymers chemistry and particularly of the olefins, in the first place of ethylene obtained from suitable fractions of liquid hydrocarbons. These productions based on petroleum had already reached a high development in the United States, but in 1949 it was still unknown in continental Europe which had many more important basic problems to face, such as alimentation, transportation, supplies, housing and the like.

Italy was one of the first countries of continental Europe to decide to build up a petrochemical industry in 1949.

The utilization of olefins preceded their production from petroleum sources. The raw materials were at that time obtained by emergency methods: the main raw material, ethylene, was obtained from ethanol. When the olefin production plants in turn were completed, the utilizing plants were ready to absorb their production. This was essential for the economy of such expensive plants and brought about a great advantage for the economy of the whole scheme.

Thus, in 1952 the first part of the program based on 10,000 tons per year of ethylene and of the same quantity of propylene had been carried out. In this way was started the first post-war production of high pressure polyethylene in continental Europe.

All this describes the situation of the Italian chemical industry and gives a glimpse of the problems presented by its development. It includes also the bulk of traditional chemical plants which were rapidly reconstructed after the heavy damages of the war on the basis of their original design. This undertaking received great help from natural gas which had, in the meantime, become available.

In this connection, the Italian ammonia and nitrogen fertilizer production methods deserve special mention, because today about a quarter of the world's nitrogen production is obtained by the Italian processes of Fauser-Montecatini or of Casale. The plants constructed all over the world according to these processes amount to several hundreds and the relevant investment is estimated to be around 1,300 million dollars.

Many Italian processes show the characteristic tendency to economize on electric and thermal energy consumptions.

Due to the fact that many important chemical reactions industrially employed are exothermic, in many cases the heat of reaction has been employed for the production of steam; in the past, not only was heat wasted but consumption of cooling water was required. It is common practice in Italy now to recover one ton of steam per ton of sulphuric acid produced or of 0.85 ton of steam per ton of ammonia produced.

The same ideas were extended also to industrial processes of organic chemistry. To give an example I wish to mention the new plant (which was object of my personal attention) for the production of formaldehyde by complete oxidation of methanol in a once through step and with a 90-92% yield of theoretical.

In this plant, not only did we eliminate the steam consumption needed in old plants, but we achieved a production of 0.4 tons of steam per ton of formaldehyde solution produced. This plant, which has a capacity of 70 tons/day, incorporated the principles of American industrial automation so that it is run by one man only.

In 1952, the production of petrochemical derivatives and of polymers enriched the existing basic situation already described. This new production of organic chemicals was carried out with the methods and in the quantities characteristic of the so called heavy chemical industry.

The first PVC plant outside of Germany was built in Italy in 1936. Its capacity was, initially, 1,200 tons/year; today the total PVC capacity in Italy is 50,000 tons/year; and the methods of production have been improved.

The factors behind the rapid growth of the heavy organic chemical industry are, on one hand, the continuously improving experience in the production of olefins and derivatives, and on the other hand the development of new uses and of new end products.

The capacity of the ethylene production of the Ferrara plant is now being expanded from the initial 10,000 to 40,000 tons/year. Other plants, in the stage of erection or on the drawing board will add another 50,000 tons/year capacity in the near future.

The Future

Before starting to examine the future outlook of the Italian chemical industry I wish to mention rapidly the present situation of the field of "man made fibres".

The production of man made fibres represents the Italian effort to rebuild the industry ruined by the war and also the recent development of fully synthetic fibres. This production is indicated in Table 5. The column which we have indicated for 1958 is based on the production of January of this year multiplied by 12; this cannot give an idea of the current development of such industry, since many new plants are in a stage of advanced construction or have been recently put in operation. There-

TABLE 3

ITALIAN PRODUCTION OF AMMONIA

Year	Metric Tons
1952	237,000
1953	294,000
1954	361,000
1955	424,000
1956	484,000
1957	484,000

TABLE 4

ITALIAN PRODUCTION OF METHANOL

Year	Metric Tons
1952	13,500
1953	14,700
1954	24,400
1955	31,600
1956	32,300
1957	38,600

TABLE 5

ITALIAN PRODUCTION OF MAN MADE TEXTILE FIBRES

	1947	1952	1957	Jan. 1958 x 12
Cellulosie Artificial Fibres				
—Viscose	5,597	75,191	126,334	119,880
—Acetate	69	2,477	7,996	9,058
—Cuproammonia process	48	1,910	2,680	2,988
	5,714	79,578	137,010	131,926
—Casein Fibres	–	893	5,616	5,910
Synthetic Fibres				
—Polyamides	17	1,249	9,027	12,087
—Polyesters	–	–	480	1,090
—Polyvinyl	–	–	977	1,100
	17	1,249	10,484	14,277
Total of Man Made Fibres	5,731	81,720	153,110	152,113

fore the actual production in 1958 may differ substantially from the one indicated in our Table 5.

To foresee the long term future in general is not an easy thing and has been called crystal ball gazing. This is even truer in the chemical field, where new solutions of old problems, new approaches and new discoveries may revolutionize old conceptions and old programs. The evolution of the chemical industry is rapid and what yesterday was the knowledge of a few, or today pioneering work, will tomorrow become acquired practice if it will not be already made obsolete by the rapid march of progress.

Each country's contributions to progress are different and are framed in its own environment, are pushed by its particular needs and are depending on its own stage of evolution.

The Italian chemical industry which was born, lived and is still living under difficult conditions, has nevertheless pioneered in some fields with new original conceptions. This is remarkable considering that any new chemical process developed in the laboratory requires expenditure of notable efforts and of substantial money in order to be transformed in a commercial plant. Certainly the future situation will depend on the progress that is now being made and progress is a consequence of fundamental research in Italy and abroad. The results of today's research will determine the new aspects of the industry in the future.

The results of a research organization depend on many factors, some of which cannot be foreseen. Such organizations now have available modern methods and tools of investigation that are powerful and fast. However, the ownership of modern equipment is not all what is needed because good minds are still essential in order to open new fields of fundamental and practical importance.

While fundamental discoveries are the work of individuals and of special aptitudes, helped by collaborators and provided with adequate means, the development of commercial plants and of the applications are rather the result of collectively organized work.

Besides, in the chemical field several years are required to move from the first laboratory conception to commercial production. This is due to the fact that chemical technology is not yet well defined and presents more variables than the other ones, and to the fact that the theory of mechanical models is, in general, not valid for chemical equipment. As a consequence, it is necessary to go through two or even more stages of pilot plants before achieving the first plant on a commercial scale.

Increasing national and international competition, which shall be speeded up in Europe by the creation of the Common Market, shall induce the chemical industry to take part in a competition for research and progress. The present expenses (ranging from 3 to 5% of the total sales) which are incurred for research by the leading chemical industries, shall be still increased. At the same time, all possible ways to make the research more efficient, shall be endeavored. Profitable results in this field are obtained more or less successfully, but it is certain that their general effect is imposing. No other industry has the dynamism of progress which moves the chemical industry.

The future Italian situation will consist in the development of the present one, promoted above all by the improvements obtained in Italy and, by the acquisition of developments made abroad. No industry, no country can aim at achieving a top position if they do not make a contribution to progress.

Chemical progress, as it has already been said, is based on research. However, research depends from another fundamental prerequisite: education.

In Italy, schools of a technical character like the schools of engineering and in particular, the chemical engineering department of the Polytechnic of Milan differ under certain respects from schools of other countries which, specially in North America, have a marked tendency toward specialization.

Our programs are very wide and we try to give to our students a theoretical background as multilateral as possible. Of course this prevents a thorough specialization in given fields. At the end of our courses chemical engineers have also a good knowledge in mathematics and in mechanical and civil engineering. In addition we offer to our students the possibility to undertake some basic research studies.

However we think that this trend is most suited to train people with aptitude to research work.

The department of chemical engineering of the Polytechnic of Milan has been, for several decades, one of the main sources of technical men for the Italian chemical industry. This is also true of men who gave a contribution to the strictly chemical research in Italy. The research laboratories of the Milan Polytechnic always had help from the Italian chemical industry and in turn have given a good contribution to its development.

Studies made in the field of catalysis and of kinetics of chemical reactions, taking into account the actual operating conditions of industrial plants, bring a better understanding of the mechanism of certain processes. Then fundamental contributions were made to have the best rational solutions in the stage of designing process and operation units for industrial plants.

The kinetic study of the mechanism of catalysis and the study of catalyst structures made at the Milan Polytechnic were conducive to original and rational solutions in the methanol synthesis and in oxosynthesis reactions and also to the economical production of formaldehyde in large size units.

Before the last war, studies on synthetic rubber made at our Polytechnic were conducive to original processes developed in the first Italian factory in this field. There was built the first unit in the world to separate, with physical methods, butadiene from butylene, by extractive distillation.

Finally an important result of research carried out at our Polytechnic with scientific methods were the recent contributions to the production of new macromolecules.

Such contributions were made by the X-ray section which developed high level research in the lattice structure of organic substances and also of complex catalytic systems, by the section of organic synthesis, by the section of kinetics of chemical reactions, by the infrared spectrographic section and by the macromolecular physical chemistry section.

The collaboration of specialists in the various sections helped in obtaining results of a fundamental scientific character, which is a basic prerequisite to the subsequent commercial developments.

The discovery of stereospecific polymers like the isotactic and syndiotactic ones, the identification of their structure, the preparation of highly stereospecific catalysts which allow to obtain at will high yields of polymers with the desired steric structure, the synthesis of high purity isotactic polymers, of stereoblock polymers, of etero-block copolymers and of random copolymers, all this opened enormous possibilities to the chemical industry.

What was the exclusive domain of nature, namely to join the monomeric units in a giant macromolecule with a predetermined steric order and not at random is now possible also to man, who also created types of macromolecular structures not existent in nature.

Man, since prehistoric times has been using, without knowing it, macromolecules having pre-ordered steric structure like clothing materials, aliments, materials of construction, but only now is he able to synthetize them in the laboratories and in industrial plants. Isotactic polymers with a high degree of crystallinity, obtained from alpha-olefins, which are very cheap raw materials derived from petroleum, will supply, in the future, materials of construction having, in the oriented state, tensile strength like that of steel, but with a one eighth of its density.

Textile fibres having some mechanical characteristics better than nylon will be obtained at low cost.

The light weight will make it possible to obtain products with insulating properties like wool and with a very pleasant feel. The low price will allow developments in the future entering the fields of classical materials of construction and the paper industry.

In the field of diolefins, industry in the U.S. has been able to produce 1-4 cis polyisoprene almost identical to natural rubber. We have been the first to produce 1-4 cis polybutadiene at a high degree of purity having the same property of natural rubber to crystallize when stretched.

The lower price of butadiene, its already existing availability and the excellent properties of the polybutadiene as sterically pure as the natural rubber, make polybutadiene, in my opinion, more interesting than polyisoprene.

However, even more interesting in the field of synthetic rubbers are in my opinion, the essentially saturated copolymers C_2-C_3 (ethylene-propylene) because of their good elastic properties, coupled with tensile strength and resistance to aging better than that of natural rubber.

Finally the extension of sterospecific processes to monomers that are not hydrocarbons completes the great revolution that is taking place in the field of macromolecules.

One of the most promising fields in the applications of macromolecules having a sterically regular structure will be that of textile fibres. Also, natural fibres (cellulose, silk) have a sterically regular structure. The new processes of stereospecific polymerization consent to obtain macromolecules starting also from highly asimmetric monomers. It is therefore possible to make fibres with high tensile strength and a high melting point starting from olefinic monomers, some of which are available at low cost. The technology of obtaining thin threads has now reached a high level stage of development, but owing to one reason or another the threadable materials are still defective in quality or high in price and man made fibres are still today only 10% of total fibre consumption. Cotton is still the king of fibres in volume of consumption. However the stereospecific catalysis will supply raw materials suitable to obtain fibres suited to various uses at a low price and this may be considered a revolutionary trend.

Going back to the whole field of the Italian chemical productions their quantitative growth will more and more promote the exports especially toward the underdeveloped areas of the world and already the exports take one third of the whole production. It is to be foreseen that the productions based on coal will remain stationary and some will decline. The electrochemical industries have a trend to limit themselves to the most traditional fields like chloro-soda and aluminum.

Another indication of the progress that takes place in technology and in industrial organization is given by the continuous lowering tendency (with some oscillation) of chemical prices, while the expenses for research, technical services, personnel and tax load are increasing. This trend may be noticed all over the world, but is particularly strong in Italy. The selling prices of basic products like synthetic fertilizers and home plastic materials are, in Italy, the lowest in the world. However this situation requires care and the continuous bringing up-to-date of methods, especially considering that the Italian productions are quantitatively modest in comparison with those of other countries, and cannot have the economical advantage of very large production units.

I have indicated some directions of the chemical progress for the next years and the Italian chemical industry will proceed along these paths with the advance due to the priority of its studies and inventions, and with the energy and initative which has been demonstrated in difficult and serious conditions.

Progress that may take place abroad will also help and will be taken into consideration and all considered we shall witness changes and benefits much greater than those brought by violent upheavals and fights among nations.

The beneficial effect of the increasing importance of the chemical industry on every aspect of human activity all over the world will be the best reward of the labors and efforts of the scientists and engineers working in this interesting field.

One of the most revoltuionary changes will be caused, as already said, by the development of processes that will build macromolecules having a predetermined structure. They will render some branches of industry independent from agriculture (in the fields of textiles of paper and of materials of construction) and make more agricultural surfaces available to production of food and feed. In a few decades this will be a strong necessity dictated by the impressive growth of world population and by the increase of the standard of living which is the aim of all countries of this planet where the beginning of peeping in the outer space cannot distract us from our earthly problems. ★ ★ ★

The Chemical Industry in the Benelux Countries

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THE Benelux countries enjoy an incomparable geographical position in the centre of the most industrialized, populated and best equipped region, as regards to lines of communication, of Western Europe.

This privileged position explains the very early development of commerce and afterwards of industries; by the Middle Ages the Low-Countries already stood out as a result of their intense activity.

And, accordingly, when the need in raw-materials came to diversify, their availability was to permit realizations which would have been impossible elsewhere.

The chemical industry had in our region, as in most developed countries, expanded greatly and become one of the important activities of our economy.

As early as 1554, a soap industry was developed in Amsterdam, followed in 1702 by the production of explosives and of sulphuric acid in 1835; nevertheless it was Belgium, which first realized an intensive status of industrialization.

Belgium's development resulted from a number of factors, including the opening up of coal fields, the proximity of the French iron-ore field of Lorraine, the creation of waterways and the equipment of Antwerp harbor. These developments favored, in the course of the last century, a rapid spreading of metallurgy and glass works, the establishment of large consumers of basic mineral reagents, the production of acids and alkalies in large quantities, and gave rise to other products such as superphosphates, glues and gelatines, mineral pigments, soaps, and the stearin industries.

This development of the heavy mineral industry has been characterized by Ernest Solvay's work.

The pioneering part played by Belgium in the field of the recovery of coke-oven products such as tar, gas and benzol is also to be remembered.

The discovery of coal in the Dutch province of Limburg, at the begining of this century, was to give Holland a basis for its industrialization. We note that there was a parallel development of carbochemistry in both countries, between the two world-wars.

As regards Luxemburg, this small country achieved a very remarkable position in the field of iron-metallurgy and by-products although the chemical industry, remained of secondary importance.

If Belgium led the way in the field of heavy industry based on coal, the Netherlands, on the other hand, took the lead as regards utilization of petroleum.

Presently, these two countries have taken the same course, not as a competition between carbochemistry and petrochemistry, but as a close collaboration and co-ordination as being the best solution for our common economy.

Belgium

As we have already pointed out, the origin of the heavy chemical industry in Belgium is connected with the development of the metallurgy industry and, more particularly, with the zinc metallurgy industry which solved the problem of transforming the SO_2 resulting from the roasting of ores into sulphuric acid.

This sulphuric acid was to lead to the production of sodium sulphate, hydrochloric acid, superphosphates, ammonium sulphate, and other chemicals.

Since 1952, the Belgian production of sulphuric acid has passed the million tons mark and the techniques used have been constantly improved.

The Solvay process for sodium carbonate production which was to revolutionize this particular industry and enable the Solvay Company to spread its activities worldwide and become one of the major producers of caustic soda and chlorine was developed in 1865.

Another industry, long established in Belgium, deals with phosphoric acid derivatives, either Thomas process slags or superphosphates prepared from natural phosphates.

Mention must be made also of the recent production, on a large scale, of sodium tripolyphosphate which is connected with the developments of the new detergent industry.

As regards nitrogen fertilizers, Belgium, as well as the Netherlands, took a marked position just after World-War I, this position was confirmed and developed during recent years.

Both these countries, because of their extensive agriculture industry had to produce enough fertilizers to cover their requirements to the largest possible degree.

The following figures show the yearly consumption in kgs per hectare, of fertilizers in Belgium and the

Netherlands as compared to West Germany, Great Britain, France and Italy:

	N	P_2O_5	K_2O	Total (1956-1957)
Belgium	54	60	85	199
Netherlands . . .	82	49	65	196
West Germany .	37	40	62	139
Great-Britain . .	26	30	24	80
France	15	26	20	61
Italy	17	23	4	44

The hydrogen required by the ammonia synthesis is mainly obtained by coke-oven gas fractionation, although the necessary amounts are supplemented by cracking either petroleum gas or fuel oils.

Ammonium nitrate is presently the principal fertilizer, nitric acid is also used to treat natural phosphates in view of producing binary or even ternary, i.e. so-called "complete" fertilizers.

Belgian production processes in the field of fertilizers were and are frequently applied for by foreign countries.

Nitric acid is also largely used in Belgium for the production of powders and explosives.

In the field of safety explosives for mining purposes, new formulae have recently been developed which promise to achieve a great success.

In the field of carbochemistry, as was mentioned before, Belgium has been amongst the first countries to equip coke-ovens for recovering by-products.

The actual production of coal-tar has nearly doubled since pre-war days; its distillation, following petroleum industry techniques, is mostly on the continuous system. A better recovery of phenols, naphthalene and anthracene is accordingly obtained.

The following productions have then been developed: phthalic anhydride, phthalates plasticizers and, more recently, maleic anhydride. These raw-materials were themselves to foster the rise of the resins and plastics field: phenoplasts, alkyds, polyvinyl and polyester resins.

The notable pioneer work of the Belgian chemist Baekeland should be emphasized here, as he originated the plastics industry.

The use of coke-oven gas containing hydrogen for the synthesis of ammonia which has fostered applications of ethylene chemistry has already been mentioned. The first step was to produce ethylene oxide (and later propylene oxide). The original processes have caused interest abroad and have led to their utilization in some foreign countries.

This is also the case as regards a new process for the preparation of acetylene from hydrocarbons.

Hydrogen is, in addition, used for pressure hydrogenation; vegetable oils have been so treated to prepare fatty alcohols.

Due to its proximity to sources of available coal, it is only recently that Belgium turned to the field of petrochemicals.

This field was established when two important refineries were erected at Antwerp, after World War II.

An harmonizing production policy between Belgium and Holland has been set up, by which, the programs along which Antwerp and Pernis operate, complement one another.

The Antwerp works, based on ethylene and propylene produced from refinery gas, has begun to prepare ethylene oxide and glycols; phenol and acetone by the cumene process together with nonene and dodecylene.

Belgium thus disposes of all the required raw-materials necessary to develop its new industry of synthetic detergents.

Soap-works represent an old and important activity of the country, and, as elsewhere, careful attention has been given to surveys of new trends in the technique.

The synthesis of anionic and nonionic detergents shows a good start.

The paint and varnish industry has always been important in Belgium. The same applies to mineral pigments production. In this line, it is to be noted that a new white titanium factory has recently been started.

Solvents, in particular chlorinated solvents prepared from acetylene and ethylene, are currently produced; to these must be added now methane chlorinated derivatives, the methane being mostly extracted from coal-pits as firedamp.

But this industry, together with the very important natural and synthetic textiles industry (viscose, cellulose acetate, nylon), required the manufacture of organic pigments and dyestuffs.

In Belgium, an attempt has been made to direct the traditional heavy chemical industry to finer achievements. Thus, since the war, the production of certain dyestuffs has been developed in connection with better availability of basic coal tar derivatives. A scale of dyestuffs of good quality is produced either for textiles, paper or paints.

Presently a new class of formazan dyes for wool and polyamide fibres is being launched.

To the latter industry, can be associated those preparing organic pesticides. In this line, a new group of naphthalene fungicides has been developed with fair prospect of success.

The pharmaceutical industry has also made great strides. In 1920, attention was concentrated on drugs for tropical diseases, but since the end of World War II, many new synthetic products have been made such as antihistaminics, curarizers, analgesics, sulphamides, antibiotics and insulin.

The exceptional position of the photoproducts industry should be mentioned. The Gevaert Company, which is the only producer, is at the fore of progress in films, papers for high speed photocopy or its remarkable "Gevacopy" process derived from the "diffusion-transfer" technique discovered in Gevaert's laboratories.

We should also mention at random, amongst many others, the sugar and margarine industries, as well as the new remarkable atomic research center in Mol.

It is also necessary to mention the liaison between the many industrial realizations reviewed and the fine scientific tradition which our four Universities impart to our engineers and research graduates.

In 1928, a National Scientific Research Fund was constituted to aid University research graduates, to provide them with particular scientific equipment, and to allow them to take part in instruction periods abroad.

Since 1945, an Institute for fostering scientific research in industry and agriculture has played a very useful part in providing grants for industrial research and to research centres which have been set up in several industrial groups.

Finally, the more and more important role played by industrial research laboratories such as those equipped by Société Belge de l'Azote et des Produits Chimiques du Marly, Société Carbochimique, Société Photo-Produits Gevaert, Société Solvay, Union Chimique Belge, etc... must be mentioned.

The Netherlands

In spite of the fact that such industries as soap, paint and varnish, explosives and sulphuric acid works have been established in the Netherlands for a very long time, it can be said that the expansion of chemical industry really dates from the beginning of the century. Since World War II it has shown a remarkable progress. As a matter of fact, between the years 1938 and 1958, the chemical industry's productions have increased three fold.

As raw-materials, the Netherlands has coal, the Staatsmijnen of Limburg's production covers two thirds of the nation's requirements, very important deposits of salt (NaCl in the North-East of the country; numerous agricultural products; and, petroleum, the recently discovered oil-fields yield 1.5 million tons per year of a very paraffinic crude and the largest oil refinery in Europe has been built in Pernis.

Sulphur must be imported as pyrite-ore but the hydrogen sulphide contained in refinery gases already plays an important part.

The very large sulphuric acid industry also delivers liquid sulphur dioxide and other numerous products such as potassium permanganate.

A new undertaking of the principal sulphuric acid manufacturer must be noted, namely, the production of catalysts for cracking, hydroforming and platforming techniques practised in oil refineries.

In connection with the sulphuric acid industry, superphosphate production has been developed on a very large scale.

One of the main problems of industry in Holland, as well as in Belgium, after the 1914-18 war, was to ensure the production of nitrogen fertilizers needed by an extremely progressive and elaborate agriculture industry.

The importance and the known high quality of agriculture in Holland are due to the remarkable government fostered organization for soil condition control, fertilizers appliance and survey of cultures.

Here also the synthesis of ammonia is based, foremost, on carbochemistry, i.e. on hydrogen extracted from coke-oven gas.

Ammonium nitrate, calcium nitrate and "mixed" fertilizers obtained by treatment with nitric acid of natural phosphates are the ones mainly produced.

An interesting original process for urea synthesis has been achieved and has had several industrial applications in the Netherlands; it will soon be used in Belgium also.

The large coke-ovens built in Limburg by the Staatsmijnen have led to a remarkable development of the carbochemistry industry. These include: the systematic valorization of coal-tar and benzol, benzene, toluene, xylenes, naphtalene, anthracene, pyridines, phenols; phthalic anhydride; and phenol synthesis and its transformation into cyclo-hexanol, cyclohexanone and caprolactam in view of preparing a textile fiber of the superpolyamide type.

We have already mentioned the working up of coke-oven gas hydrogen whose hydrogen sulphide is in turn transformed into sulphuric acid. Ethylene is processed as ethylalcohol and, presently, as polyethylenes as well, either by high pressure or by catalytic process according to the Ziegler technique.

The Dutch deposits of sodium chloride has been the basis for the development of an active industry producing caustic soda, chlorine and their derivatives, and yields hydrochloric acid, hypochlorites, chlorates and sodium hydrosulphite.

Four enterprises have recently joined in a partnership to erect a large sodium carbonate plant in Delfzijl.

The value of natural and agricultural products has long since been upgraded in the Netherlands.

The old-established soap-industry is prosperous and is noted for its modern equipment; synthetic detergents have also been given full attention.

Production of gelatines, casein, starch, dextrin, and fermentation alcohol, is also notable.

Several companies are specializing in essential oils and flavors as well as in the preparation of food products.

The very important development of a petroleum refinery in the Netherlands 15 million tons of crude per year will be soon processed will allow for large applications in the field of petrochemicals; thus a cut of paraffins is cracked in α olefines leading, by sulphatation, to detergents; ethylene is transformed into ethylene dichloride in view of preparing vinyl chloride and vinyl resins; propylene leads, on the one hand, to isopropyl alcohol and acetone, and on the other hand, to epichlorydrin and the new Epikote resins.

Two recent developments must also be mentioned: Aldrin, Dieldrin and soon Endrin pesticides and synthetic glycerin—the preparation of the latter will constitute the first works of this kind in Europe.

It can be been, as we mentioned before, that this development program does not interfere with the scheme operated in Antwerp.

In the Netherlands, as well as in Belgium, chemical industry must obviously aim at fine and evolved productions.

Synthesis of pharmaceuticals has rapidly been intensified in recent years; the production of vitamins, antibiotics, hormones, insulin, and other numerous famed preparations has supplemented the former preparation of alcaloids.

This branch of industry, as well as that of dyestuffs, which is initiated also in the Netherlands, aims as well, at preparing more and more pesticides, which are expected to find a large local outlet.

Plastics processing is underway at many works.

Also very important, is the synthetic fibres industry. In addition to the manufacture of viscose, cellulose, carboxymethylcellulose, mention must be made of a polyamide fiber (and resins) based on caprolactam which is obtained from phenol.

The rapid progress of the chemical industry in the Netherlands has mainly been due to the quality of the staff-personnel available.

The chemical tradition of high schools in Holland is well established; its professors have been and still are authorities.

The part assumed in this respect by Delft Technical University needs no stressing and, in face of greater demands for qualified chemists, a second Technical University is being created in Eindhoven.

The excellent education given to laboratory assistants in the Netherlands should definitely be emphasized.

Moreover chemical industry can also rely on the remarkable Dutch Centre of Industrial Research (T.N.O.) founded by the State in 1934.

This Centre has fostered and supports a score of specialized Institutes devoted to the various fields of industrial activity. It comprises also a large central laboratory and a central technical institute working for those interested in solving definite problems on the basis of research-contracts, much in the way the Battelle and the Mellon Institutes operate in the United States.

The Centre is comprised of about 1300 persons of whom more than 200 are university graduates. And to underline the degree of interest shown by the industry, the amount of its participations has been, in 1956, two and a half times as much as in 1951.

Finally certain chemical companies have set up important laboratories which have secured a wide and justified reputation. Among others are: The Algemeene Kunstzijde Unie, the Bataafsche Petroleum Maatschappij, Lever Brothers, Organon, Philips, and the Staatsmijnen.

The question is sometimes raised as to what small countries can do in actual world-wide competition. Our opinion is that their enterprises should aim not only at exporting their original techniques, but, above all developing these techniques so that they may become the brains activating large industrial groups as has been accomplished by some of the companies just mentioned above.

We shall assign now, with a few figures, the place of the chemical industry of Belgium and the Netherlands

	BELGIUM	THE NETHERLANDS
Employees	54,000	65,000
Turn-over (U.S. $)	500 millions	580 millions
Exports (U.S. $)	260 millions	270 millions

As regards the part played by the BENELUX Union, it can be characterized by the evolution of exchanges between the two countries.

	1948	1956
Belgium to the Netherlands (U.S. $)	19 millions	37.8 millions
The Netherlands to Belgium (U.S. $)	7.4 millions	22.4 millions

It was hardly possible, in the limits alloted to this paper, to state all of the chemical achievements of the BENELUX Countries, we hope nevertheless that we have succeeded in giving you a sufficiently expressive survey.

Conclusions

We think that one can be confident in the industrial future of Belgium and the Netherlands.

The BENELUX countries enjoy the benefit of free enterprise. Moreover they have but slight customs protection, are bounded by powerful neighbours, and are obligated to export most of their production. Thus, for these reasons, they are not likely to discover the virtues, or even the excesses of competition. At the dawn of the Common Market, they need not train to adopt economical liberty. In short, there will, it seems, be but few artificial structures to be modified.

Indeed, their small internal markets have not often permitted their industries to reach the optimum scale and has, up till now, inevitably limited the research effort; this research effort will henceforth have to be intensified in view of the larger economical frame at hand.

Our enterprises, as in most industrial countries, apply more and more to self-financing, but endeavour, on the other hand, to palliate the disadvantage of too narrow dimensions by particular forms of organization. Thus large financial groups often ensure the necessary impetus and indispensable coordination.

We wish to note, also, that the BENELUX countries have just undergone, with success, a particularly important experience. In spite of difficult circumstances, such as the marked differentiation of wages between Belgium and the Netherlands, the exchanges between these two countries were intensified more than had been foreseen.

The different fields of their industries have been submited to a severe adjustment, but most of them have overcome this trial.

We are aware of being about to face the necessity of a new effort of modernization, or even of reconversion or concentration. Each of our countries will have to direct its course according to its particular assets, and will have to behave with imagination; the goal to be reached being to harmonize complementary, rather than competitive, economies.

The BENELUX countries have tried to exemplify what should become, in liberty, the organization of our world.

I will conclude by wishing that the World Fair which opens in Brussels, may also contribute to the narrowing of ties which unite the people and to improve their relations both on economical and cultural grounds.

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Certain Trends in the Development of Chemistry and the Chemical Industry in the U.S.S.R.

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During recent years, chemical science and the chemical industry of the Soviet Union have made very considerable progress; one indication of this is the launching of the first artificial earth satellite. It would have been impossible to launch this satellite without the participation of the chemical industry, for modern rocketry places heavy demands on the chemical products and materials that it uses. All these materials are successfully produced by the Soviet chemical industry.

Some idea of the development of the U.S.S.R. chemical industry may be gained from the following fact: the volume output of the chemical industry in 1956 was 4.7 times that of the prewar 1940 level. In some of the categories the growth in production is still greater. The percentage increase in 1956 over that of 1940 is as follows: in artificial fibres—1160, in plastic masses—855, in automobile tires—376, in mineral fertilizers—336, sulphuric acid—271, etc.

A still more rapid development in the chemical industry is envisaged for the coming years with considerably greater appropriations for the construction of new plants. As in previous years, investments will be made in those branches of industry that make for a higher living standard of the people. High priority will be given to the production of fertilizers and chemicals for protecting plants. This will help to raise crop yields and thus expand the output of food products and also the industry of artificial fibres, plastic masses and other materials directly concerned with the output of consumers' goods.

The successful development of the chemical industry is directly due to the extensive research conducted by a very large number of research institutes, chemical plants, and by the Academy of Sciences.

In a brief report it is impossible to encompass all the multifarious trends in scientific investigation and all the achievements of chemical production, for they are bound up with the output of many thousands of products and materials produced by the chemical industry of the country, and are the result of the study of thousands of chemical reactions and processes.

At the present time the chemical industry of the Soviet Union produces all the principal modern products and materials required by allied branches of industry and by agriculture. These include synthetic fibres, modern plastic materials based on exceedingly diverse compounds, chemicals protecting plants (DDT and its analogues), phosphoro organic preparations, organic compounds of mercury, different phenols, hexachloro-cyclohexane and many others, chemicals for fighting weeds (2,4-D and its derivatives, trichloro-acetates, esters of polyethylene-glycol, etc., dyes, pharmaceutic preparations, antibiotics, and many others. Ethyl alcohol and other substances are produced in large quantities from petroleum gases.

However, like in any other normally growing organism there is an extra demand for certain products; this makes it necessary to develop still more rapidly the production of a series of new materials. The exceedingly rapid development of agriculture calls for a fast and expanded output of products necessary in the obtaining of higher yields.

The rapid development of the chemical industry became possible due to the organization of a broad network of research institutions both in the various branches of industry as well as in the Academy of Sciences, and the academies of the union republics.

From the very first years of Soviet power, higher educational establishments encouraged the development of the old schools of science and also began to create, one after the other, new scientific research organizations whose aim was to promote the development of the different branches of industry and inorganic and organic chemistry. Among these organizations are the following: The Russian Institute of Applied Chemistry (later renamed the State Institute of Applied Chemistry), The Karpov Physico-chemical Institute, The Institute of Fertilizers (now the Scientific Institute of Fertilizers and Insecto-Fungicides, or NIUIF), The State High-Pressure Institute, The Scientific Institute of Semi-products and Dyes, The Chemical Pharmaceutic Institute, The Plastics Institute, and institutes of artificial fibres, of the nitrogen industry, of synthetic caoutchouk, rubber, synthetic alcohols, and many others.

Without touching on questions concerning the development of physical and inorganic chemistry by such brilliant investigators as N. S. Kurnakov, I. A. Kablukov, P. A. Rebinder, A. N. Frumkin, N. N. Semenov, G. G. Urazov, I. V. Grebenshchikov, I. I. Chernyaev, V. G. Khlopin, A. N. Terenin, V. I. Vernadsky, A. P. Vinogradov, I. P. Alimarin, I. V. Tananaev, S. I. Volfkovich, and many others, I shall attempt to give a broad picture of some of the trends in the field of organic chemistry.

First in this field are the works of the numerous followers of N. D. Zelinsky and A. E. Favorsky on different transformations of aliphatic, alicylic, and aromatic hydrocarbons. Of great technical significance is the reaction of dehydrogenation of different hydrocarbons, which can be used as a basis in the production of such products as styrene, butadiene, methylstyrene, ethylene, propylene, acetylene, and many others. Hydrocarbon transformations of this type have been studied in detail by N. D. Zelinsky and A. A. Balandin and their coworkers. As you know, the first of these hydrocarbons serve as raw material for the production of certain important types of synthetic rubber.

It may be mentioned that due to the work of S. V. Lebedev and his followers, the U.S.S.R. was the first country in the world (1932) to organize a large-scale industrial production of synthetic rubber. In this important field of industry, priority undoubtedly belongs to the Soviet chemists and technologists. At present the Soviet Union produces a large number of synthetic rubbers, each with its specific peculiarities suited to the different fields of technology. At present, only the U.S.S.R. is industrially producing butadiene-methylstyrene rubber, which has superior properties to butadiene-styrene rubber. Synthetic rubbers have also been developed on the basis of other hydrocarbons too; also acrylic rubbers, vinyl-pyridine (that stand up well under low temperatures and swell less in organic solvents), polyurethane rubbers, and many others. Vinyl-pyridine rubbers are obtained by means of the copolymerization of butadiene and 2-methyl-5-vinyl-pyridine and retain elasticity in the temperature range from −55 to +200°C. Of great interest is isoprene rubber which was synthesized in the U.S.S.R.

In recent years, increasing importance is being attached to siliconic caoutchoucs, the rubbers of which retain their properties in the temperature range from −600 to +250°C. These rubbers are also stable under the action of ultraviolet radiations, water, ozone, and many other chemical and physical agents. Rubbers have also been found that do not lose their properties at temperatures over 300°C, which is a significant factor making them useful in various new branches of technology.

Besides the rubbers already mentioned, the U.S.S.R. produces many other types obtained by copolymerization of dienes with unsaturated halogeno derivatives of hydrocarbons and with other unsaturated compounds containing different functional groups. Also in production is butyl rubber.

Of the reactions of the transformation of different classes of hydrocarbons, mention should be made of the reactions of aromatization of aliphatic hydrocarbons, which are of interest in a number of processes concerned with amelioration of motor fuel, and also the synthesis of certain homologues of benzene. Again exceedingly interesting are the reactions of alkylation of hydrocarbons in the presence of boron fluoride and other catalysts, the isomerization of aliphatic and cyclic hydrocarbons with the inter-transition of six- and five-membered cycles (B. A. Kazansky, N. D. Zelinsky et al.), hydrogenation, oxidation, halogenation, nitration, sulphochloration, etc.

The diverse catalytic transformations of hydrocarbons studied by Soviet chemical schools have served as material for the development by A. A. Balandin of the multiplet theory of heterogeneous catalysis, which is based on the principle of a structural and energy correspondence between the substrate and the catalyst.

The reaction of the nitration of cyclohexane and its analogues which was developed by S. S. Nametkin and his coworkers may be utilized for the industrial production of polyamides. An interesting technical method of obtaining polyamides on the basis of the reaction of telomerization has been developed by A. N. Nesmeyanov, R. Kh. Freidlina and their coworkers. The reaction of carbon tetrachloride with ethylene and a series of subsequent transformations have served as a basis for obtaining a new type of synthetic fibre-"enant" and "pelargon". In addition to synthetic fibre, plastificators, lubricants, and aromatics have been synthesized from the products of the reaction of ethylene and carbon tetrachloride and have been studied.

In this case, amino-enanthic acid and amino-pelargonic acid are obtained according to the following scheme:

$$Cl(CH_2)_n CCl_3 \longrightarrow Cl(CH_2)_n COOH \longrightarrow NH_2(CH_2)_n COOH \quad \ldots\ldots (1)$$

Methods for the synthesis of α-amino acids have been worked out. These include natural amino acids (proline, ornithine, lysine, glutaminic acid, α-amino-adipinic acid, α-amino-suberic acid, phenylalanine, η-chloro-phenylalanine, etc.) and their homologues and analogues. All these acids are easily obtained by the general scheme:

$$Cl(CH_2)_n CH_2CCl_3 \quad Cl(CH_2)_n CH = CCl_2 \quad X(CH_2)_n CH = CCl_2 \ldots (2)$$

$$X(CH_2)_n CHCl\,COOH \qquad X(CH_2)_n CHNH_2\,COOH$$

A new type of telomerization was recently discovered by A. N. Nesmeyanov and R.Kh. Freidlina in the case of the reaction of ethylene and methyl-dichloro-silane, phenyl-trichloro-silane, triethyl-silane, etc.:

$$RSiHCl_2 + nCH_2 = CH_2 \longrightarrow R\overset{Cl}{\underset{Cl}{Si}}(CH_2CH_2)_nH \ldots (3)$$

An extensive cycle of studies of the transformations of acetylene compounds was carried out by the school of A. E. Favorsky. Here, mention should first of all be made of the numerous and interesting investigations of I. N. Nazarov and collaborators and M. F. Shestakovsky on the synthesis and study of the transformations of different vinyl esters.

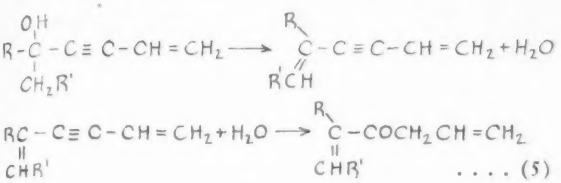
Among the reactions of acetylene hydrocarbons discovered by Favorsky, one of the most interesting is their condensation with cetones. This reaction proceeds in the presence of powdered potassium hydrate, and in the simplest case may be represented by the scheme:

$$CH_3COOH_3 + HC \equiv CH = (CH_3)_2\overset{OH}{\overset{/}{C}}-C \equiv CH \ldots (4)$$

In the condensation of acetone with vinyl-acetylene we obtain vinyl-acetylenyl-dimethylcarbinol, which readily polymerizes with the formation of polymers with good adhesion properties, which fact made it possible to utilize it for the production of a so-called carbinol glue.

Starting with this and analogous alcohols, Nazarov and coworkers carried out a large number of different syntheses of unsaturated substances, cyclic and heterocyclic compounds.

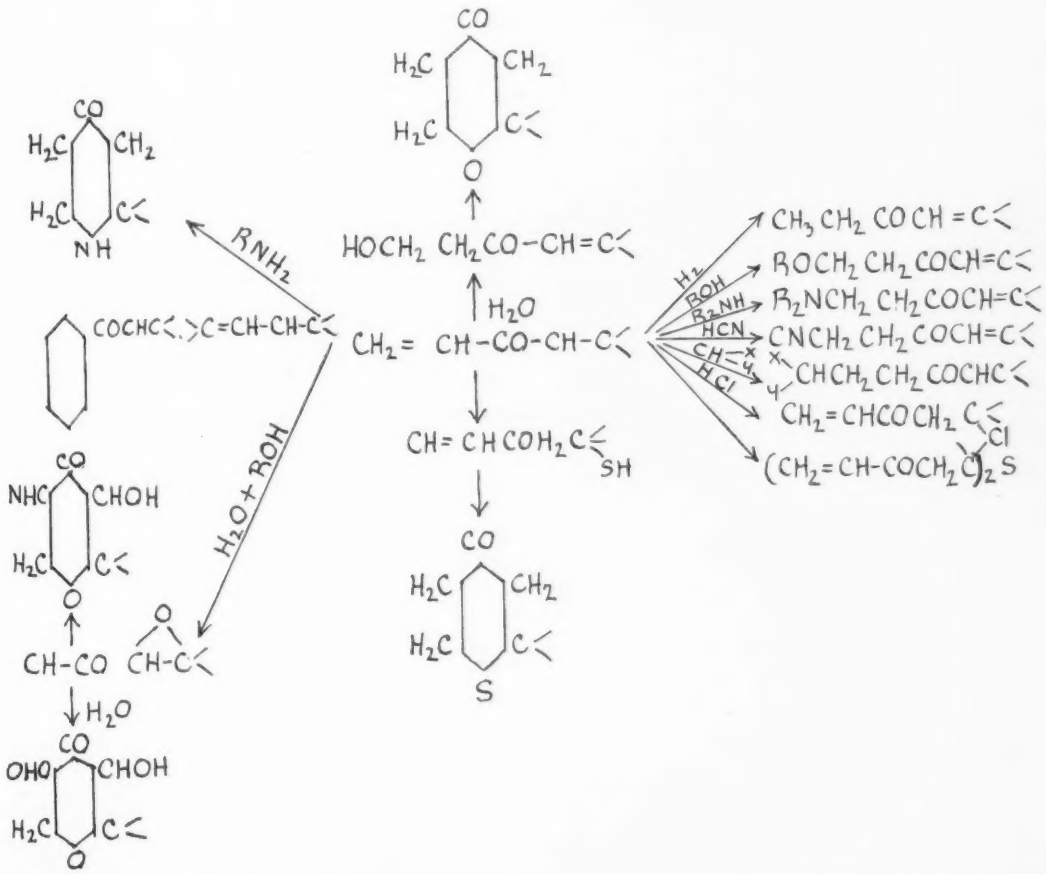
The cycle of transformations accomplished by Nazarov and coworkers may be represented by the following general schemes:



. . . . (5)

of β-chloro-vinyl-alkyl-ketones are given in the general scheme on page 126.

Extensive research has been conducted in the U.S.S.R. in the processing of petroleum hydrocarbons, both for their use as motor fuel, lubricants, and also for processing into diverse chemical products. Of the products of the chemical processing of natural gases and petroleum hydrocarbons, mention should first be made of the synthesis of halogeno derivatives of hydrocarbons, alkylene oxides, surface active substances, lower and higher alcohols, carboxylic acids and other technically important products. In



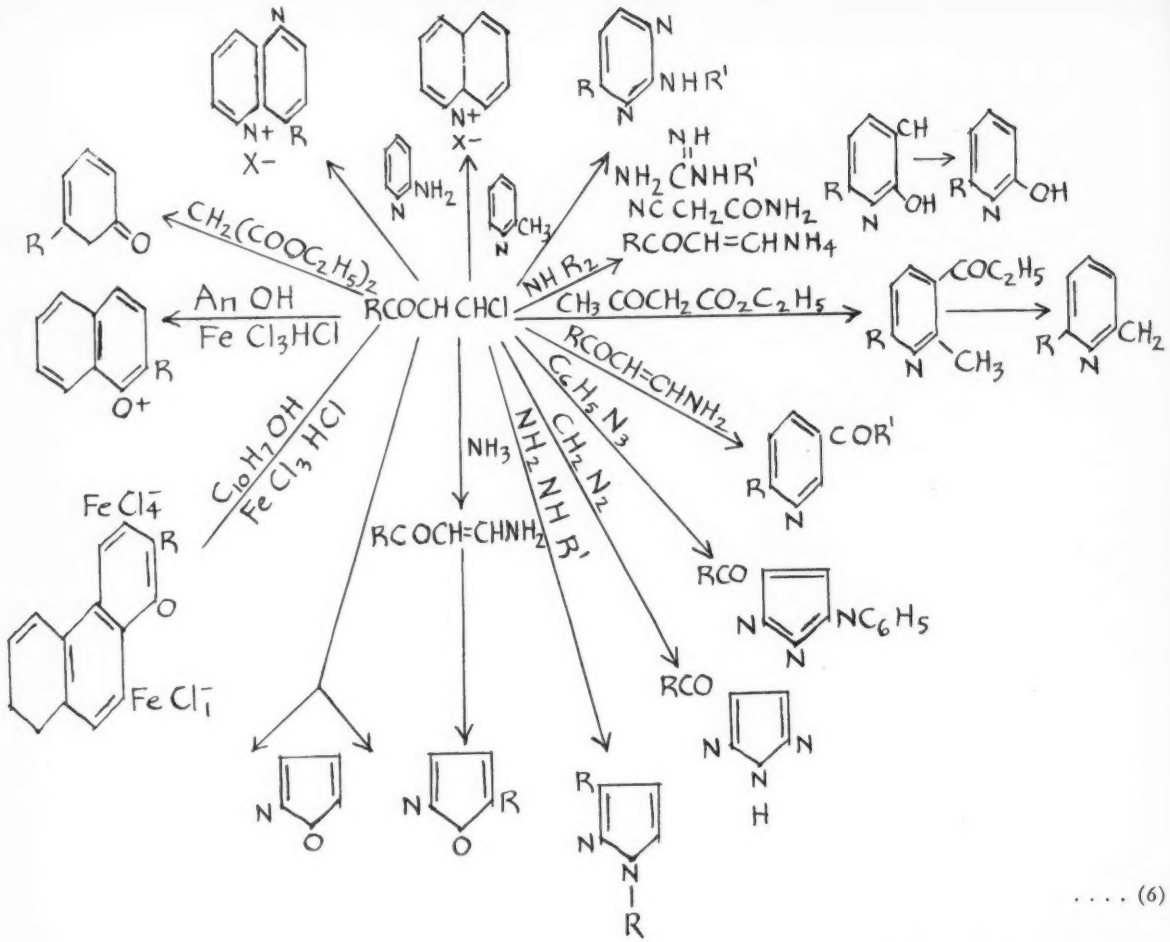
Utilizing vinyl-alkyl-cetones in the reactions of the diene synthesis, Nazarov and coworkers synthesized substances close in structure to the natural styroids. The application of the diene synthesis for the synthesis of polycyclic systems has made it necessary to study the structural directivity of these reactions. In a large number of examples it was possible to show that the conditions of the reaction and the character of the substitute in diene and dienophil produce an essential effect on the course of the process and the structure of the final products of the reaction. In working out the reaction of guided synthesis of stereoisomers it was possible to obtain all four of the theoretically possible isomers of octaline-4-dicarboxylic acid and seven out of eight possible decaline-1,2-dicarboxylic acids.

Interesting investigations into the synthesis of a large number of different heterocyclic compounds were carried out by A. N. Nesmeyanov, N. K. Kochetkov and others. The initial products of these syntheses were β-chloro-vinyl-alkyl-ketones. Some of the trends of transformations this trend, mention should be made of the work of S. S. Nametkin, A. V. Topchiev, B. A. Kazansky, N. I. Shuikin, K. P. Lavrosky, and others.

In addition to the study made of aliphatic compounds and their application in indusrty, much has been done on derivative aromatic hydrocarbons that are needed in the production of dyes, pharmaceutic preparations, and chemical means of protecting plants and fighting weeds.

It is to be noted that the Soviet Union, as early as 1949, organized large-scale industrial production of phenol via the peroxide of isopropylbenzene, and at the present time this method is used to produce phenol at a number of chemical factories (P. G. Sergeev). Further investigations showed that this method may be used to obtain other phenols and ketones too.

Among works of practical nature mention should be made of a method of producing 2,4-dichloro-phenoxy-acetic acid by chloration of water dispersion of phenoxy-acetic acid in apparatus with mixers of original design;



. . . . (6)

the same method is used to obtain a 90% yield of 2-methyl-4-chloro-phenoxy-acetic and butyric acids.

Of interest also is the photochemical production of hexachloro-cyclohexane in high-power column apparatus. The technical hexachlore-cyclohexane obtained in the photo-chemical chloration of benzene may be processed in one stage into a preparation containing 90% gamma isomer with a yield of not less than 85-90%, taking account of the gamma isomer in the technical product. The non-toxic isomers of hexachloro-cyclohexane are good raw materials for the production of a number of valuable products that may be used both in agriculture and in industry.

Speaking of the processing of aromatic compounds, mention should be made of the development of the analine-dye industry and first of all of the production of dyes. During the postwar period the chemical industry began to produce a large number of new dyes, among which are 47 direct (substantive), 11 colored sulphurous, 16 products for cold dyeing, 68 acid and mordant-type for wool, 7 basic, 41 pigment and lacquer-type, 42 cubic, etc. These figures show that it is only during the past few years that the chemical industry has begun to put out over 250 new dyes that belong to different classes of organic compounds. Simultaneously with the growth in assortment of dyes and pharmaceutic preparations there developed an industry that produces semi-products necessary for their synthesis.

On the basis of aromatic raw material, large-scale production (with a large number of different types) has been organized of polymer materials, including synthetic fibre and plastic masses, in addition to dyes and pharmaceutic preparations. We may also point to the large-scale production (on the basis of aromatic compounds) of chemicals for the protection of plants, such as DDT, trichlorophenolate of copper (for cotton-seed treatment against hommosis), poly-halogeno-phenols, dinitroalkylphenols and many others.

Investigations of element-organic compounds have been greatly extended in recent years. Russian chemists have been interested in metallo-organic compounds since the time of A. M. Butlerov. Some of the most outstanding representatives of Russian chemical science, such as A. M. Zaitsev, S. N. Reformatsky, P. P. Shorygin, N. D. Zelinsky, and many others have worked in this field and have made their contribution to the development of this important branch of organic chemistry. Interest in this field is due to the important part which element-organic compounds play in the solution of many problems of theoretical and applied chemistry. It is sufficient to recall that such important discoveries as establishing the valency of the elements, the discovery of free aliphatic radicals, the obtaining of new stable materials, and others resulted from investigations in the field of element-organic compounds. Also well-known is the role of many metallo-organic compounds in organic synthesis and their highly diversified application in different branches of industry and agriculture. Thus, they find application as raw material

for the production of materials that are very resistant and stable with respect to aggressive media, and antiknock agents for motor fuel, admixtures to lubricants, insecticides, fungicides, seed-treatment agents, herbicides, and in many other cases.

During recent years in the Soveit Union, investigations have been made of the organic compounds of the following elements: lithium, sodium, magnesium, zinc, cadmium, mercury, boron, aluminium, thallium, silicon, titanium, zirconium, germanium, tin, lead, chromium, selenium, phosphorus, arsenic, antimony, bismuth, bromine, iodine, fluorine, iron, and platinum.

Outstanding in their investigations in the field of element-organic compounds in the U.S.S.R. are the schools of A. E. Arbuzov, A. N. Nesmeyanov, B.A. Arbuzov, I. L. Knynyants, K. A. Kocheshkov, and others.

To date, a large number of methods have been worked out of the synthesis of different elements-organic compounds; numerous types of new compounds have been obtained and many of them have found practical applications. The abundance of new material has made it possible to draw certain fundamental conclusions that are of importance not only for the chemistry of element-organic compounds, but for all organic chemistry as well.

Below we give several illustrations of the synthesis of element-organic compounds.

The synthesis of element-organic compounds by means of double onium salts discovered by Nesmeyanov in 1929 has been widely applied for the synthesis of organic compounds of mercury, thallium, tin, lead, bismuth, arsenic, antimony (Nesmeyanov, Kocheskov, Markova, Reutov, and coworkers). In its general form, the reaction of obtaining element-organic compounds by this method may be represented by the following general scheme:

$$(Ar N_2 X)_m\ Me X_n + \frac{zm}{p} Me' \longrightarrow Ar_m Me X_{n-m} + \frac{m}{p} Me' X_p^{z} + N_2 \quad \ldots\ldots (7)$$

This method is a general and simple way of obtaining individual metallo-organic compounds containing diverse functional groups in the aromatic radical.

In connection with the investigation of the diazomethod a study has been made of the decay mechanism of diazonium and other onium compounds; it is shown that it is possible to control the reaction and to guide its course either according to the ionic or the radical type.

Very interesting results have been obtained in studying the decomposition of boron fluoride of phenyldiazonium in chloro-benzene and bromo-benzene. In this respect it was possible to synthesize hitherto unknown simple aromatic compounds of polyvalent chlorine and bromine:

$$Ar N_2 BF_4 + Ar X \longrightarrow Ar_2 X^{+} BF_4^{-} + N_2 \quad \ldots\ldots\ldots (8)$$

By substituting other anions for the anions of boron fluoride, Nesmeyanov and coworkers made a study of a large number of salts of diphenylchloronium and diphenylbromonium. The double salts of diarylhalogonium with the salts of metals were also used to synthesize organic compounds of mercury, tin, antimony, and bismuth (Nesmeyanov, Reutov, Makarova).

$$(Ar_2XCl)_m Me Cl_n + \frac{zm}{p} Me' \longrightarrow Ar_n Me X_{n-m} + \frac{m}{p} Me' X_p \quad \ldots\ldots\ldots (9)$$

The diazomethod was applied by N. N. Melnikov, K.D. Shvetsova-Shilovskaya and Grapov to obtain mixed esters of thiophosphoric acids:

$$(RO)_2 PXOH + Ar N_2 Cl \longrightarrow (RO)_2 PXSAr + N_2 + HCl \quad X = S,O \ldots (10)$$

The same authors developed a method of synthesizing esters of arylphosphonic acids from diakylhalogenophosphites and the respective salts of diazonium:

$$(RO)_2 PCl + Ar N_2 Cl \longrightarrow (RO)_2 PCl_2 N_2 Ar \xrightarrow{H_2O} (RO)_2^{P=O} Ar + N_2 + 2HCl \quad \ldots\ldots\ldots (11)$$

Of great importance in the chemistry of element-organic compounds are reactions linked by transitions from one set of element-organic compounds to other sets. Nesmeyanov and coworkers have developed numerous pathways of such transitions, especially between the organic compounds of mercury, on the one hand, and compounds of zinc, cadmium, aluminium, thallium, tin, lead, arsenic, antimony, bismuth, and polyvalent iodine, on the other hand.

Kocheshkov and coworkers recently worked out a method of the direct introduction of thallium into the aromatic ring:

$$C_6H_6 + Tl(OCOC_3H_7\text{-}i)_3 \longrightarrow C_6H_5 Tl(OCOC_3H_7\text{-}i)_2 + i\,C_3H_7 COOH \quad \ldots\ldots\ldots (12)$$

An interesting method of the synthesis of metallo-organic compounds is the reaction of metal substitution recently marked out by Kocheskov and Talavieva:

$$C_6H_5 Zi + Mg \text{ (and also Hg, Sm, Pb, As, Sb)} \longrightarrow (C_6H_5)_2 Mg \text{ and also } (C_6H_5)_2 Hg, (C_6H_5)_4 Sn, (C_6H_5)_n Pb, (C_6H_5)_3 As, (C_6H_5)_3 Sb \quad \ldots\ldots\ldots (13)$$

A new method of the synthesis of organic compounds of mercury of the aliphatic series was worked out by G. A. Razuvaiev and coworkers:

$$CH_3CO_2 Hg OCOCH_3 \longrightarrow CH_3 Hg OCOCH_3 + CO_2 \quad \ldots\ldots (14)$$

This reaction is initiated by peroxides.

The Frankland-Duppas method has been used in the U.S.S.R. for the industrial production of seed-treatment agents. Due to the work of N. N. Melnikov and coworkers this method has produced yields of dialkyl mercury up to 70-90% of the theoretical value. In connection with the industrial production of mercuric agents for seed treatment, Nesmeyanov, Melnikov, and coworkers have made a rather detailed study of the reaction of dialkyl and diaryl mercury with mercuric salts of acids of different basicity. As a result of these investigations it has been possible to find conditions for producing alkyl-mercuric salts of poly-basic acids with yields close to the theoretical values.

The syntheses have been worked out of substituted alkyl mercuric salts by combining the salts of mercury with unsaturated compounds (Nesmeyanov, Freiolina, Borisov).

The classical method of obtaining organic compounds of phosphorus is the Arbuzov rearrangement discovered by A. E. Arbuzov as far back as the beginning of this century. During recent years this method has been used to synthesize a large number of new compounds some of which are of great practical importance for use as medical preparations. New directions in the Arbuzov rearrangement have been discovered, as you know, the Arbuzov rearrangement is still the basic method of synthesizing aliphatic organic compounds of phosphorus.

Recently, B. A. Arbuzov and A. N. Pudovik worked out a new method of producing organic compounds of phosphorus by combining diakylphosphites through double linkage of unsaturated compounds; this method has been used to synthesize over one hundred different compounds.

$$(RO)_2PHO + \diagdown C = C \diagup - y \xrightarrow{RONM} (RO)_2 \underset{\underset{O}{\|}}{P} - \underset{\underset{I}{|}}{C} - CH - y$$

Abramov, a pupil of A. E. Arbuzov, has made a study of the reaction of diakyl-phosphites with aldehydes which was the basis in the production of the well-known insecticide depterex, obtained by condensation of dimethyl-phosphite with chloral. And the reaction of obtaining dimethyl-phosphite from phosporus trichloride and methanol may be combined with the joining of chloral.

A. E. and B. A. Arbuzov and coworkers made a detailed study of the production of pyrophosphates, thiopyrophosphates, dithio pyrophospates and their different derivatives.

A method has been developed for the obtaining of different phosphorus compounds by the interaction of halogeno phosphorus with ethylene oxide, aldehydes and the like (M. I. Kabachnik).

$$PCl_3 + 3\underset{\diagdown\ \diagup}{CH_2 - CH_2}\underset{O}{} \longrightarrow P(OCH_2CH_2Cl)_3$$

$$PCl_3 + RCHO \longrightarrow R\underset{\underset{Cl}{|}}{C}H - POCl_2 \quad \ldots\ldots\ldots (16)$$

A. V. Kirsanov discovered a new class of organic compounds of phosphorus obtained by the interaction of halides of phosphorus with sulphamides and amides of different acids

$$Ar\,SO_2\,NH_2 + PCl_5 \longrightarrow Ar\,SO_2\,N = PCl_3 \longrightarrow$$

$$Ar\,SO_2\,N = P(OR)_3 \quad \ldots\ldots\ldots (17)$$

Among the compounds obtained there are interesting system insecticides that are practically harmless to warm-blooded animals.

In connection with the great importance of the different derivatives of thiophosphoric acid, which find wide application in agriculture as active insecticides and acaricides, of great significance is the obtaining of esters of chloro-thiophosphoric acid. Melnikov and Mandelbaum and coworkers have worked out a number of new and simple methods of obtaining these compounds. The most important of those methods may be represented by the following general schemes:

$$PSCl_3 + 2ROH + 2NaOH \longrightarrow (RO)_2PSCl + 2NaCl + 2H_2O$$

$$ROPSCl_2 + R'OH + NaOH \longrightarrow (RO)PSCl(OR') + NaCl + H_2O$$

$$2ROPSCl_2 + (R'O)_2Mg \longrightarrow 2(RO)PSCl(OR') + MgCl_2$$

$$3PSCl_3 + 2Al(OR)_3 \longrightarrow 3(RO)_2PSCl + 2AlCl_3 \quad \ldots\ldots (18)$$

Especially good yields are produced by dimethylchlorothiophosphate and methylethylchloro-phosphate, on the basis of which a number of insecticides are produced. A distinguishing feature of these methods of obtaining dimethyl–and methylethylchlorothiophosphates is the fact that the reaction proceeds with an almost equivalent quantity of the appropriate alchohol in the presence of an hydrous alkali.

A study of the properties of $PFCl_3$, alkyldichloro-thiophosphates and dialkylchloro-thiophosphates has shown that these compounds have properties that differ but slightly from the chloro anhydrides of different other organic and inorganic acids, on the basis of which a method has been worked out to obtain dialkylchlorothiophosphates through the interaction of $PFCl_3$ or alkyldichlorophosphate and the appropriate alchohols by the reaction:

$$PSCl_3 + 2ROH \longrightarrow (RO)_2PSCl + 2HCl$$

$$ROPSCl_2 + R'OH \longrightarrow (RO)PSCl(OR') + HCl \quad \ldots\ldots (19)$$

The same method may be used to obtain diakylchlorothiophosphates with different hydrocarbon radicals.

Of great interest are the works on tautomerism of the organic compounds of phosphorus, for example, the tautomerism of esters and other derivatives of phosphorous acid discovered several decades ago by A. E. Arbuzov and verified by his school on extensive experimental material, and also the works of Nesmeyanov and Kabachnik on the dual reaction ability of organic compounds which was studied in detail by them in reactions of various derivatives of the acids of phosphorus and certain other compounds.

It may be noted that an extremely rapid development of work in the field of silicon-organic compounds began after K. A. Andrianov discovered polymer silicon-organic compounds. In work conducted together with numerous coworkers, Andrianov showed the polymer character of the products of hydrolysis of mixed silicon-organic compounds and worked out a large number of ways of synthesizing these compounds. At the present time, organic compounds are used to produce diverse materials such as varnishes, rubbers, plastic, etc. There is no doubt that this field of industry of polymer silicon-organic compounds will continue to develop at a very high rate, because in many cases silicon-organic polymers possess exceedingly valuable properties as compared with other polymer products.

The second important stage in the development of the chemistry of high-polymer silicon-organic compounds is the discovery by K. A. Andrianov and A. Zhdanov of a new class of polymers–poly-organo-metallo-siloxanes. The structure of this group of polymers may be represented by the following general formula:

$$-\underset{|}{\overset{|}{Si}} - O - \underset{|}{\overset{|}{Al}} - O - \underset{|}{\overset{|}{Si}} - \quad -\underset{|}{\overset{|}{Si}} - OC_2 - O\underset{|}{\overset{|}{Si}} - O - \quad \ldots\ldots (20)$$

Polymers of this sort possess valuable properties and have already found practical application in industry. They readily dissolve in organic solvents; after the evaporation of these solvents, they form films.

To this same group belong the work on the synthesis of the organic compounds of titanium which was conducted by Nesmeyanov, Freidlina, Nogina, and Brainina,

who obtained different esters of titanium acid of the following structure:

$$(RO)_3Ti-O-Ti(OR)_2-O-Ti(OR)_3 \quad \ldots\ldots\ldots (21)$$

During recent years, considerable development has been apparent in the chemistry of the organic compounds of fluorine, which are of great practical and theoretical interest. In the U.S.S.R., studies in this interesting field are developing in several directions both as to methods of obtaining these substances and reactions of different substances of this class and as to their practical utilization in industry. First to be mentioned here is the work of I. L. Knynyants and coworkers dealing with a method of obtaining fluoro alkanols by the interaction of alpha-oxides and hydrogen fluoride:

$$CH_2\!-\!CH_2 + HF \longrightarrow FCH_2CH_2OH \quad \ldots\ldots\ldots (22)$$

Knynyants and his coworkers have also made a broad investigation of numerous reactions of the linking of nucleophilic and electrophilic reagents to fluoro-olefines, they have studied the order of combination of alcohols and mercaptans to unsymmetrical fluoro-olefines, they have established facts of the vinyl substitution of fluorine atoms by alkoxyl and they have shown allyl rearrangements of perfluoro-allyl derivatives.

These same investigators have made a study of the reaction of nitration of different fluoro derivatives of ethylene and its homologues; and it has been established that in addition to dinitro-compounds, and sometimes in preference to them, there are formed β-nitroperfluo-akyl-nitrites, which upon saponification produce α-nitroperfluo-carboxylic acids.

$$CF_2NO_2COOH$$

$$CF_3CFNO_2COOH \quad \ldots\ldots (23)$$

Unlike the ordinary α-nitroalkylcarboxylic acids, such acids are completely stable and are distilled without decomposition.

Perfluo-vinylmagnesium-halogenides too have interesting properties, through the utilization of which it was possible to obtain perfluo-acrylic acid and other compounds (Knynyants, Fokin, and others).

Extensive research has been conducted in the U.S.S.R. also in the field of the heterocyclic compounds of various series. These investigations are connected with the names of the Soviet chemists V. M. Rodionov, I. L. Knynyants, Iu. K. Iuriev, A. E. Porai-Koshits, B. A. Porai-Koshits, M. V. Rubtsov, Giller, Mndzhoyan, Ya. L. Goldfarb, and others.

It is impossible in a brief report to cover all the diversity of work being carried on by Soviet investigators in this interesting and important field, I shall therefore mention only a few that are of a general nature. Mention should first be made of V. M. Rodonov and coworkers. On the basis of a general method, discovered by him, of obtaining β-amino acids by means of the interaction of aldehydes and ammonia and malonic ester:

$$RCHO + NH_3 + CH_2(COOH)_2 \longrightarrow RCH(NH_2)-CH_2COOH + CO_2 + H_2O \quad \ldots\ldots\ldots (24)$$

he developed a simple and convenient method of obtaining hexahydropyridines. The production of such compounds may be represented by the following scheme:

$$RCH(NH_2)-CH_2COOH + NH_2CONH_2 \longrightarrow \text{(NH, R-O, C=O, } H_2C\text{, NH, C=O)} + NH_3 + H_2O$$

$$RCH(NHCOR')-CH_2COOH + SOCl_2 \longrightarrow RCH(N{=}C(R')Cl)-CH_2COCl + NH_3 \longrightarrow \text{(RCH, CR', } H_2C\text{, NH, C=O)}$$

$$R\text{-}CH(NHCOR')-CH_2CONH_2 \xrightarrow[NaOH]{NaOBr} [R\text{-}CH(NCOR')-CH_2-NCO] \longrightarrow R\text{-}CH(NCOR')-CH_2-NH-CO \longrightarrow$$

$$\longrightarrow RCH(NH)-CH_2-NH-CO + R'COOH \quad \ldots\ldots (25)$$

The significance of β-amino acids for living organisms is well known.

Speaking of the synthesis of amino acids it is necessary to point to the works of I. L. Knynyants and coworkers devoted to obtaining and studying α-oxy-α amino acids, which showed that α-substituted-α-acyl-amino acids are easily obtained from α-,β-dihalogeno-α-acyl-amino acids through the interaction of the latter with water, alcohols, mercaptans and other such compounds:

$$X-CH_2-C(X)(COOH)-NHCOR \xrightarrow{Hg} {}^{*}CH_2-C(Y)(COOH)-NHCOR + HX \quad \ldots (26)$$

Y = OH, OR, NHR, SR, NHCOR

*Hg should read Hg

The second atom of the haloid element is substituted in more rigorous conditions. It was in this way that the substituted derivatives of serine and cistein were obtained for the first time:

$$XCH_2-C(X)(COOH)-NHCOR \xrightarrow[H_2O]{RSH} RSCH_2-C(SR)(COOH)-NHCOR$$

$$HOCH_2-C(NHCOR)(COOH)-NHCOR \quad \ldots\ldots (27)$$

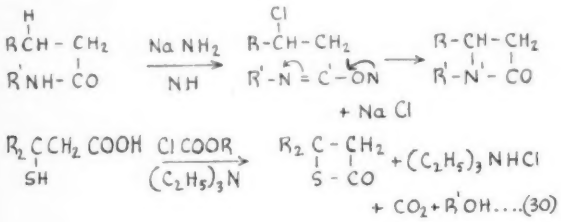
New oxasalons that contain different functional groups in the position of the 4-oxasolon ring have been synthesized by means of anhydridization of α,β-dihalogeno-α-acyl-amino-carboxylic acids with PCl_5 or thionyl chloride:

$$XCH_2-C(X)(COOH)-NHCOR \xrightarrow[(CH_3CO)_2O]{PCl_5} XCH_2-C(a)=N-C(O)-CR \quad \ldots\ldots\ldots (28)$$

M. M. Shemyakin developed a method of obtaining α-oxy-α-acyl amino acids by hydrolysis of 2-phenyl-4-bromoxsalons:

$$\text{(Br CH, N, O=C, } CC_2H_5\text{, O)} \xrightarrow{H_2O} HOCH(COOH)-NHCOR \quad \ldots\ldots (29)$$

Interesting results have also been obtained by Knynyants and coworkers in the synthesis of four-membered heterocyclic compounds—β-lactams and thiolactones:



In such a brief review as this is it was hardly possible to indicate even all of the principal trends of Soviet investigators in synthetic organic chemistry. I was therefore compelled to give only isolated illustrations that were in large measure selected subjectively, which was inevitable because of the tremendous abundance of the material. But I believe that the examples given are sufficient to show that serious attention in the U.S.S.R. is paid to the development of organic chemistry, and to the natural-chemical industry of organic synthesis, which plays an important part in satisfying the demands of the people for vitally important goods and materials.

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The Training of Engineers for the Chemical Industry at the Leningrad Technological Institute

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During the early stages, the development of higher technical education in Russia was closely connected with the chemical problems of the mining industry. Attention was already being given to the training of chemists during the reign of Peter the Great (1672-1725), when a start was made in training specialists for the analysis of ores and metals. From the middle of the 18th century, under the initiative of M. V. Lomonosov (1711-1765), systematic training of chemists of higher qualifications was begun in Russia. In a chemical laboratory, well-equipped for its time, the pupils of Lomonosov carried out work in general, analytical, physical, and applied chemistry, skillfully combining physico-mathematical and chemical methods. A strictly quantitative approach prevailed in the research work at this laboratory. The pupils of Lomonosov developed into chemists well-versed in mathematics and physics.

The opening of the Moscow University in 1755 provided a national facility for the training of a substantial number of specialists of higher qualifications, among them chemists, research scientists and teachers. This fact, in turn, made it possible for Russia to open additional institutions for higher education. The first institution for higher technical education in Russia, Saint Petersburg Mining Institute, was established in 1774. In addition to mining, the students of this school also studied chemistry and the chemical foundations of metallurgy. In the early part of the 19th century, when the application of chemical processes was rapidly developing in the textile, leather, and sugar industries, an acute need of engineer-technologists developed in the country. In that connection, Saint Petersburg Technological Institute was established in 1828. Following related curricula and syllabi, the Institute trained technological-mechanical and chemical engineers. Among other disciplines, the students of this Institute thoroughly studied physics, applied chemistry, and chemical and mechanical technology [1]. G. I. Gess, the pioneer of thermo-chemistry and one of the founders of this Institute, has unquestionably played an important role in the organization of chemical education at this Institute.

Fifty years later, that is by 1879, the students of the Technological Institute studied 32 subjects. A single syllabus was followed in teaching the majority of subjects included in the curricula, such as mathematics, physics, inorganic chemistry, thermodynamics, strength of materials, applied mechanics, technology of metals, technology of construction materials, engineering drafting, drawing, structural arts, architecture, geodesy, foreign language, political economy, and certain other subjects related to chemistry and mechanics.

Later on, courses in applied electricity, physical chemistry, general chemical technology, and industrial chemical processes and apparatus were introduced as regular subjects of instruction. Furthermore, the chemistry students in addition studied analytical chemistry, organic chemistry, technology of the mineral substances, anatomy and plant physiology, mineralogy, technology of organic substances, food technology, and dye technology.

Many outstanding scientists taught at the Technological Institute, among them D. I. Mendeleev; metallurgist D. K. Chernov; the author of a well-known handbook on organic chemistry, F. F. Beil'shtein; physico-chemist G. I. Gess; technologists I. I. Andreev, A. K. Krupskii, S. V. Lebedev, P. P. Fedot'yev, and N. L. Shchukin; well-known chemist A. A. Yakovkin, A. E. Favorskii, A. E. Porai-Koshits, D. P. Konovalov, and V. Ya. Kurbatov; and physicists B. L. Rozing, R. E. Lents, and others.

The training of engineer-technologists, chemical and mechanical, in pre-revolutionary Russia [2] was characterized by the curriculum common to both in the first three years of instruction, by a thorough preparation in the general theoretical and engineering subjects, and by a close tie between the study of theory and practical work in laboratories, shops, plants, and factories. In giving broad training, the aim was to develop chemical engineers who also possessed a good knowledge of mechanical engineering and mechanical engineers who were familiar with the essentials of the technological processes.

Higher technological training in pre-revolutionary Russia had made some progress. There were three technological institutes, in Petrograd, Kharkov, and Tomsk, and four technological faculties in the polytechnic institutes. Shortly before World War I these institutes and faculties had an enrollment of nearly 10,000 and the number of graduating engineers was 200-230 per year—a much smaller number than the number of 1957 graduates from the "Lensoviet" Leningrad Technological Institute alone.

In 1918, the Lenin decree "On Admission to the Institutions of Higher Education of the RSFSR" established

that "Proletarians and poorest peasants must be unconditionally ahead of others and that stipends be made available to them on a large scale".

Our progressive state, having widely opened the doors of educational institutions for all men and women of all nationalities, having abolished tuition, and having established stipends for the overwhelming majority of students including all who are in need, in a short time achieved a complete democratization of the higher school and assured its rapid growth [3].

At the present time there are more than 750 institutions of higher education in the country, including 195 institutions of higher technical education with an enrollment of 700,000. Almost every large city in the U.S.S.R. has become a center of higher technical education. In many educational institutions instruction is conducted in the language of the local national minority [4].

The training of engineers for the chemical industry was being rapidly expanded in conjunction with a vigorous progress of that industry in the U.S.S.R.

At the present time there are approximately 40 technological institutes in the country and about as many technological faculties at the polytechnic and other institutes [5]. The number of graduates in 1955 included 4,954 trained in chemical technology; 1,855 in forestry engineering and wood, cellulose, and paper technology; 3,454 engineer-technologists in food, textile, and light industry technologies; and a large number of mechanical engineers. Furthermore, a substantial number of research scientists, with a degree of *kandidat* of chemical or of technical sciences, have also been trained at the technological institutes [6].

Students are admitted to the institutions of higher education on the basis of competitive entrance examinations in one's native language and literature, mathematics, physics, chemistry, and one foreign language. At the Leningrad Technological Institute there are usually several applicants for each vacancy.

The Training of Engineers for the Chemical Industry

A characteristic peculiar to the chemical industry is that the investment in plant and power facilities is proportionately much greater than in other industries [2]. In 1940, the capital outlay per worker in the chemical industry in the U.S.S.R. already averaged 32,000 rubles—approximately ten times as large as in the textile industry and twice as large as in the metallurgical industries [7]. At the present time the latest apparatus, devices, and automatic equipment for the regulation and control of the chemical processes are being intensively introduced in the chemical industry. It follows that the modern engineer-technologist must equally well be trained in chemistry and chemical technology and in the application of new techniques in the manufacturing processes—such as automation and the use of isotopes [2].

In the course of time the curricula of the Leningrad Technological Institute prescribed for the training of the engineer-technologists had undergone considerable changes in connection with the changing requirements of the industry.

Before the Revolution nearly 65% of time was given to engineering subjects. In those days a practicing engineer-technologist was also obliged to perform the functions of an engineer-constructor.

In the 1930's the study of specialized subjects was intensified, with up to 25% of the curricular time being given to such subjects. This practice developed in consequence of a need for specialists who would be able immediately to assume duties in the various plants and factories of the then vigorously growing industry.

In recent years the technological institutes of the Soviet Union have been given the task of giving a broad training to the specialists. In this connection the curriculum of the Leningrad Technological Institute allots about half the time for the study of theoretical subjects, about one-third for engineering subjects, and only 13.6% for specialized subjects.

The point is that engineer-technologists, chemical and mechanical, are trained in the specialties offered at the Leningrad Technological Institute for work both at the enterprises of the chemical industry proper and at other plants where chemical processes are used extensively, such as in the petroleum, coke, food, textile, and light industries; in construction materials, machine building, instrument building, and other industries. An engineer, graduate of the Institute, is qualified also to work in the organizations specializing in design and in scientific research institutes. Such a wide diversification requires the engineer to have a very broad technical outlook and a sufficiently solid grounding in higher mathematics, physics, chemistry, electrical engineering, electronics, industrial chemical processes and apparatus, strength of materials, and other engineering subjects.

The great multiplicity of technological processes and of the related equipment, the introduction of automation, the diversity of measuring and control devices—all make it necessary for the engineer to master creatively a wide range of subjects. He should be able to analyze and to synthesize the results of the work performed by the apparatus, machines, and installations; to develop, on the basis of empirical data, new technological processes and apparatus and to improve the existing ones, aiming at a more intense rate of production and the lowering of manufacturing cost of output.

In accordance wtih these requirements the development of the Institute's curricula continues in the direction needed for a broad training of specialists.

The course of training at the Institute follows one or another plan of instruction (*uchebnyi plan*) which, for every specialty offered, lists the subjects of study and the order in which they are to be studied, the schedule of tests and graded examinations, and the schedule of industrial practice training. For the majority of specialties the term of instruction is 5 years; for certain more complex specialties the term is 5 years and 6 months.

Table 1 shows the structure of the curricular plan presently in effect at the Leningrad Technological Institute for the training of chemical and mechanical technologists.

The humanities and socio-economic group of subjects includes the history of the Communist Party of the Soviet Union, political economy, dialectical and historical materialism, industrial economics, industrial organization and planning, and a foreign language.

Physico-mathematical sciences comprises mathematics, physics, and theoretical mechanics.

The chemical science group of subjects is made up of general and inorganic, analytical, organic, physical, and colloidal chemistry.

The group of subjects in mechanical engineering comprises descriptive geometry and drafting, strength of materials, theory of mechanisms and machines, machine details, thermotechnics, electrotechnics, structures, and metallurgical technology.

The subjects in chemical engineering include general chemical technology, industrial chemical processes and

TABLE 1

THE CURRICULAR PLAN OF THE LENINGRAD TECHNOLOGICAL INSTITUTE FOR THE TRAINING OF TECHNOLOGICAL ENGINEERS FOR CHEMICAL INDUSTRIES

Category of Subjects	Chemical Engineers			Mechanical Engineers		
	No. of Subjects	Class Hours	%	No. of Subjects	Class Hours	%
1. Socio-economic and Humanities	6	624	14.0	6	624	14.0
2. Physico-mathematical	3	660	14.9	3	756	17.0
3. Chemical	5	1,110	25.0	1	320	7.2
4. Mechanical Engineering	7	850	19.0	8	1,530	34.5
5. Chemical Engineering	4	452	10.1	7	614	13.8
6. Specialized Subjects	4	600	13.6	3	460	10.3
7. Physical Education	1	136	3.2	1	136	3.2
Total	30	4,432	100.0	29	4,440	100.0

apparatus, automation in chemical enterprises, safety engineering, and a course on the corrosion of metals.

The specialized subjects include courses on the chemistry and technology in the particular area of specialization and on the mechanical equipment in the enterprises of the corresponding branch of industry. Within these specialized subjects, the study of problems in the design of plants, machinery, and apparatus for the chemical industry is deemed to be of considerable importance.

Lectures, seminars, and practical work in the laboratories, shops, and in industrial enterprises constitute the basic forms of instruction.

The students' class schedule provides not more than six hours per day. The students' work in the laboratories, shops, drafting rooms, and the reading rooms, is planned for a maximum independence. In the course of training, the students, to substantiate their progress, carry out certain computational and graphic assignments and paricipate in the laboratory work and in other colloquia.

Examinations in the subjects prescribed by the curriculum are held at the end of each semester. Ungraded tests (*zachety*) are taken by the students as a means of demonstrating the completion of certain requirements prescribed by the curricular plan after they complete such computational and design problems and laboratory assignments.

No fixed time is provided for the taking of such tests except that all *zachety* must be completed prior to the end-of-the-semester examinations.

During the three to four weeks set aside for examination following each semester, the students are examined in not more than five subjects.

In order that the students may develop habits of working independently and master the methods of engineering design and computation, the academic plan provides for computational assignments in heat technics and economics and for a number of term projects—on machine details, processes and apparatus in chemical and specialized and technologies, and others. The graphic component of each project calls for from three to five standard sheets of drawings.

During the term of study at the Institute, the students are given three periods of industrial practice at the leading industrial enterprises.

The first, general engineering industrial practice period of four weeks follows the completion of the third year of study. During this practice period the students familiarize themselves with the general organization of a plant, its power and water supply systems, its boiler plant installation, the repair and maintenance work done at its machine shops, its material handling equipment, and also with the selected technological processes of production.

At the end of the eighth and the ninth semesters, the so-called technological and pre-diploma practice periods of eight weeks each respectively are provided, embracing an appropriate field of work.

During the technological practice period the students study industrial technological processes in depth, and also study the methods of quality control of the raw materials, semi-manufactured, and finished goods. During the entire period of this practice the students work at the technologically most important actual work stations and in the plant laboratories.

During the pre-diploma practice, which, as a rule, is carried out at the plants specializing in work which corresponds to the topic of the student's diploma project, the students familiarize themselves not only with the technology of the subject production but also with the organization and functions of the basic and auxiliary components of the plant, technical production records, planning, personnel, plant economy, and the organization of repairs and maintenance.

The information acquired during the pre-diploma practice is used by the student in the preparation of his diploma project.

The assignment of students to all types of industrial practice is carried out in accordance with the prior agreements negotiated between the Institute and industrial enterprises.

The preparation of a diploma design or research project constitutes the concluding phase of training. The student is given his assignment for the diploma project before he leaves for the pre-diploma practice.

The entire tenth semester is set aside for the preparation of the diploma project or of the diploma research.

The topics for the diploma projects are frequently given to the students, in agreement with the industry, and they usually comprise a project on a single plant or

a single shop. The project involves computation of the materials, fuel, and power requirements of production and calculations on the basic apparatus, means of material handling, and plant communications. A budgetary study is also made, including estimates of the capital requirement for plant and machinery and of the manpower requirement; unit requirements for raw materials, steam, water, and power; and data on the automation and control of production and the safety measures.

The drawings of the project include flow charts; a plan and a cross-section view of the building showing sufficiently well the placement of equipment; drawings showing the construction of one or two basic units of the apparatus; and a diagram for the automatization of one or another of the production lines. The graphic part of the diploma project takes from seven to nine standard drawing sheets. Computations and explanatory notes take from 80 to 120 pages.

Instead of a diploma project, certain students, those who have a predisposition toward scientific research, may be allowed to carry out a diploma research assignment in the chemistry or technology of production related to the student's area of specialization.

The diploma design or research projects are publicly defended by the students at a session held by the State Examining Commission, which is usually presided over by a well-known engineer, designer or technologist. A preliminary evaluation of the completed design or research diploma project is made by an officially appointed reviewer, an engineer with experience in the corresponding type of production. By a successful defense of the project the student qualifies himself as an engineer-technologist.

Some of the institutions of higher education, those which have accumulated sufficient experience, including among them our Institute, also train engineers under individual curricular plans. To a still greater extent than the general curricula do, the individual curricular plans at our Institute take into account the trend toward broad mechanization, electrification, and automation in the chemical industries, the use of atomic energy and of a variety of new materials. The individual curricular plans, which are used not only by a number of technological institutes but also by many polytechnic institutes but also by many polytechnic institutes, reflect scientific interests and aims of the professors and teachers and the scientific and pedagogic traditions [8].

It is a known fact that the quality of instruction to a considerable degree depends upon the level of development of the scientific research activities of the teachers. Every teacher, along with the reading of lectures and the conduct of laboratory and practical instruction, also is engaged in scientific research. The Institute's research is financed by the Government through a regular budget and, in addition, by the industry under negotiated contracts.

In order to give at least some idea on the direction of the Institute's research, the following examples may be cited.

The Institute's Chair of Chemical Plant Equipment does research on the problems of automation in the chemical processes. The Chair of Technology of Inorganic Substances studies the kinetics of the heterogeneous processes in inorganic technology and, in particular, the adsorption of gases in the "foam" layer. The Chair of Processes and Apparatus does research in the kinetics of typical processes of chemical technology. The Chair of Electrochemistry studies the mechanism of electro-crystallization. The Chair of Glass conducts scientific studies on the problems of cold-working of glass and on the electric properties of glass. The Chair of Atomic Physics investigates photo-nuclear reactions in heavy nuclei and also works in the area of radio luminescence. The Chair of General Chemistry studies the methods of the synthesis and physico-chemical properties of the complex compounds of a variety of elements.

As previously mentioned, industry finances major research projects of the Institute. Thus in 1957 the total cost of research done at the Institute under industrial agreements amounted to nearly nine million rubles.

In 1957, large-scale research laboratories were created at the Institute for the faculties of Nuclear Physics, Analytical Chemistry, and Organic Chemistry for research on the most important scientific problems in the respective areas of science. These laboratories have the latest equipment and their staffs, in addition to the teaching members of the faculties, include individuals engaged only in research. Similar laboratories have been recently established for certain additional faculties.

Students, members of the Student Scientific Society and graduate students, participate in the research work of the faculties.

A senior professor acts as a scientific counselor of the student society. The results of research done by students are reported at a special scientific session held annually by the Institute. The U.S.S.R. Ministry of Higher Education awards prizes for the outstanding research done by students.

From time to time the Institute holds extramural scientific conferences on the branches of science in which the research done by the Institute has been particularly active. Conferences in which many chemists of the U.S.S.R. participated were recently held, for example, on the problems of sorption and the preparation of sorbents, on enamels, on the complex compounds, on the theory of coloration and the synthesis of pigments.

In 1957 an extramural scientific conference was held on the methodological problems of teaching analytical chemistry in the institutions of higher technical education, and, among other questions, on the teaching of the physico-chemical methods of investigation in the course of analytical chemistry.

The results of research and of methodological studies done by the scientists of the Institute are widely published. Beginning with 1957, the publication of two scientific journals devoted to the work by the chemists at the U.S.S.R. institutions of higher education, was organized at the institutions of higher technological education in Moscow and Ivanovo. In 1957 the members of the Institute's faculty published 36 monographs and textbooks, running altogether to 438 printer's sheets*; 13 issues of the Institute's journal, *Trudy Leningradskovo tekhnologicheskovo instituta imeni Lensoveta*, were published, running to 133 printer's sheets; and many articles in other scientific journals of our country.

The Students and Their Organizations

The overwhelming majority of students (about 80%) are given stipends, the amount increasing yearly from the freshman year on. The stipends of students whose grades are outstanding are increased by 25%.

In case of need a student can obtain a lump-sum assistance from the student organization.

The stipends are alloted by a committee with an active participation of student representatives. Out-of-

*Approximately 7,000 pages, at 16 pages per printer's sheet. (*Translator*)

town students live in well-equipped dormitories at a cost of 15 rubles per month. Medical services are free. In the event of illness the stipend continues for a period up to one year. Many students, without any cost to them, use sanitariums and rest-houses maintained by the Professional Unions. In 1957, at the Institute's expense, a special sports camp in a wooded area was organized for the students.

Various student organizations are active at the Institute, and their representatives sit at the Council of the Institute with a right to vote.

The student Professional Union, which includes nearly all students of the Institute as members, plays an important role. The governing body of this organization, the Committee of the Professional Union, is elected by the students each year by means of secret ballot. The Committee guides the many activities of the student body through its sub-committees – such as educational, cultural and social, student life, and other sub-committees – and also through the Faculty Bureaus of the Professional Union.

The members of the faculty exert day-to-day influence upon the students' general upbringing, their aim being not merely to instruct the youth but also to inculcate the highest human qualities: diligence, respect of the fellow human being and the fruit of his labor, the sense of civic duty, the spirit of internationalism, and others.

A student newspaper with a large circulation, *Tekhnolog*, and the many bulletin-board papers published at the Institute reflect all the notable events in the life of the Institute and the nation.

The work of cultural enlightenment carried by the student organizations at the Institute is most vividly revealed in the artistic avocations of the students. Nearly 500 young men and women participate, under the guidance of experienced art directors, in activities of the choral society, theatre workshop, solo vocal group, piano music group, folk instrument orchestra, choreographic group, the graphic arts studio, and others.

The students readily engage in sports, participating in all kinds of competitive sport and games. There are 817 members in the Institute's Sport Club which has 20 sections, including sections of Alpinism, tourism, artistic gymnastics, swimming, soccer, volley ball, hockey, boxing, light athletics, skiing, and others. Furthermore, 1,890 students, the majority of whom are members of the Student Volunteer Sports Society, engage in sports outside the Sports Club.

In such a manner the Leningrad Technological Institute and other technological institutes trains technological engineers, chemical and mechanical, for the chemical plants, plant laboratories and research institutes, in design bureaus, and as members of the faculty at the institutions of higher education; mechanical engineers work at the chemical and machine building plants and design bureaus.

The training of engineers at the Institute is organized so that its graduate chemical engineers could easily handle various devices and apparatus and its graduate mechanical engineers could readily deal with the fundamentals of chemical processes. All are brought up in the spirit of the scientific tradition of the native schools of higher education, while at the same time they are brought into a communion with the best achievements of the world science and culture.

Conditions have been created at the Institute for a free development of individual abilities and scientific interests of the youths, for the formation of their character and their physical development. Every year hundreds of young specialists trained at the Institute enter life as responsible citizens of the U.S.S.R., bringing their knowledge and culture to the people.

This translation of the Russian text was prepared by Alexander G. Korol, Center for International Studies, Massachusetts Institute of Technology, Cambridge, Massachusetts.

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